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Clinical Polymorphism of Cutaneous Leishmaniasis caused by *Leishmania aethiopica*: Association with Nutritional Status in Affected Patients, Amhara Region, Ethiopia. A Retrospective Study in Remote Areas

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Abstract: Background: The different disease forms of cutaneous leishmaniasis (CL) are influenced by parasite and host factors. Malnutrition impairs immunity. It has been found to disrupt immune protection by favoring the production of anti-inflammatory prostaglandins over pro-inflammatory cytokines. In Ethiopia, data on CL patients' nutritional status remains scarce. This study aims to assess clinical polymorphism and its association with the nutritional status of the patient. **Methods:** A retrospective study conducted from June to July 2024, and patient's data was analyzed from those treated for CL. Nutritional status was assessed through MUAC, Z-score, and BMI. **Results:** A total of 217 CL patient's statuses were nutritionally defined and 22% of them were found malnourished. Most of the CL problems concentrate on age <18 years and found mainly affected groups than others 23 (27%). Malnutrition explained more in MCL (30%) and Repeat/recurrent patients (38.5%) than in LCL (20%) and new CL cases (21%) respectively. In Early disease onset, the malnutrition level was higher than in later times (29%) versus (17%). **Conclusions:** The burden of Malnutrition is high in CL patients and might modify the clinical variability like CL forms, treatment response, and polymorphism of the disease.

Keywords: Cutaneous-leishmaniasis; Clinical-polymorphism; Dermatology; Malnutrition; Ethiopia.

1. Introduction

Leishmania parasites are intracellular pathogens that manipulate host macrophages through DNA methylation and GP63 metalloprotease, leading to a range of clinical manifestations [1]. In progressive leishmaniasis, amastigote replication and dissemination to new macrophages contribute to pathogenesis, with these cells serving as the primary reservoir for the parasite [2]. The clinical presentation of cutaneous leishmaniasis (CL) ranges from localized (LCL) to mucosal (MCL) to diffused (DCL) forms. This is influenced by both parasitic genomic diversity and the host immune response. Diffuse forms can be difficult to treat due to the large amount of parasites present. Mucosal leishmaniasis (MCL) is primarily found in immune-compromised individuals and usually presents with fewer parasites in lesions [2–5]. Despite the genomic similarity among *Leishmania* species, the relationship between genetic differences and the diverse manifestations of the disease remains complex [2]. Patients with CL who exhibit a cell-mediated response typically present with LCL, whereas those who do not show a T-cell response may develop DCL [2].

Leishmaniasis, prevalent in tropical regions, is increasing due to urbanization and environmental changes. CL lesions may develop weeks to years after a sand fly bite, appearing as

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firm, cratered ulcers. Resolution typically takes 3 to 18 months, with 10% escalating to severe forms [3–6].

Amastigotes thrive in lysosomes, causing disease in humans; microscopy identifies them with 70-75% sensitivity, especially in newer lesions [7]. The healing process for CL can be prolonged and may not result in a complete sterile cure [2]. Mucosal disease typically requires a longer treatment duration and is more challenging to cure [7]. There is no vaccine to prevent leishmaniasis infection [8]. The clinical presentation of CL and disease severity can be affected by nutrition as well as geographical location and disease endemicity [3,9]. High expression of IL-10, IL-12, and IFN-gamma mRNA was associated with a worsened outcome of lesions. The macrophage-activating effects of IFN-γ may be hindered by IL-10 expression [10].

CL is classified as a group of diseases and falls under the category of neglected diseases [11]. Malnutrition leads to immune deficiency marked by impaired delayed cutaneous hypersensitivity [12]. Asymptomatic carriers of leishmaniasis can harbor parasites long-term, influencing disease foci [13,14].

Maintaining optimal nutritional status is crucial for promoting health and preventing and treating diseases. Research has shown that weight loss of 10 percent or more can lead to negative outcomes and prolonged hospital stays [15,16]. The study on American Tegumentary Leishmaniasis revealed a potential association between CL and nutritional status. Low weight and hypoalbuminemia were significantly correlated with MCL and lesion healing process [17].

The underlying causes of the different manifestations of CL are caused by *Leishmania aethiopica.* (The major causative parasite in Ethiopia), are not fully understood. Host immunity might be one of the factors that determine the different clinical manifestations of CL. Host immunity is again influenced by the nutritional status of the host.

This study aimed to assess the nutritional status over the clinical characteristics of CL patients in the Amhara Region Ethiopia.

2. Results

2.1. Demographic Characteristics of CL Patients

A total of 217 cutaneous leishmaniasis (CL) patients were assessed for nutritional status, with a mean age of 26.7 years and a range of 1 to 79 years. In Malnourished patients, it was 25.5 years, while in nutritionally normal CL cases, 27.2 years. Among the CL participants, 59 (27%) were females, highlighting a significant number of male cases visiting the treatment centers (χ2:45; $p < 0.05$) [Table 1]. The age distribution of patients with CL revealed that those in the age group of ≤18 years old had the highest number of cases, accounting for 41% (n=89) of the total cases. The difference in the occurrence of CL disease among the age interval was significant (χ2: 77.7; $p<0.05$) [Table 1].

Table 1. Demographic characteristics of cutaneous leishmaniasis patients.

Variables	Frequency	%	χ^2:(df):p-value
Age (year)			
≤18	89	41	77.7:(3):0.000
19-40	82	38	
41-60	35	16	
>60	11	5	
Total	217		
Sex			
F	59	27	45:(1):0.000
M	158	73	
Total	217		

2.2. Clinical Polymorphism of CL Patients

Among CL patients, LCL was more common at 81%, ($p<0.05$). Furthermore, 64% of patients delayed seeking medical care for over six months, with some waiting up to 97 months ($p<0.05$).

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Additionally, 42% had lesions equal to or larger than 4cm², reflecting the condition's severity [Table 2].

Table 2. Clinical polymorphism and the test for goodness of fit: observed versus expected values.

Variables	Frequency	%	χ^2:(df):p-value
Chronicity of the disease			
0-6month	73	36	7:(1):0.000
>6month	129	64	
Total	202		
CL category			
LCL	176	81	83:(9):0.000
MCL	41	19	
Total	217		
Lesion size			
<4cm²	120	58	5:(1):0.02
≥4cm²	87	42	
Total	207		
Microscopic examination			
Positive	199	97	181:(1):0.000
Negative	6	3	
Total	205		
Treatment history			
New	204	94	168: (1):0.000
Repeat (recurrent)	13	6	
Total	217		

2.3. Magnitude of Malnutrition and Associated Factors

Our study found that 22% of individuals with CL were malnourished, with the highest rates among those aged ≤18 years. Statistical analysis revealed a significant relationship between age and nutritional status ($p<0.05$). Additionally, malnutrition was more prevalent in females (27%) than in males (20%). Notably, patients who were in the early time of CL infection exhibited higher malnutrition than chronically ill patients 29% and 17% respectively. A statistical relationship was observed between nutritional status and chronicity (onset of disease) ($p<0.05$). Similarly, more MCL clinical types were malnourished compared to the LCL category. Likewise, more repeat /recurrent patients for anti-leishmaniasis medication were found malnourished than their counterparts, with new cases at 38.5% versus 21% respectively[Table 3].

Table 3. Malnutrition across different variables in cutaneous leishmaniasis.

Variables		Malnutrition		χ^2:(df):p-value
		Yes (%)	No (%)	
Age category				
	≤18	23 (27)	63 (73)	9.8:(3):0.02
	19-40	13 (16)	69 (84)	
	41-60	6 (17)	29 (83)	
	>60	6 (55)	5 (45)	
	Total	48	166	
Sex category				
	F	16 (27)	43 (73)	1.1:(1):0.27
	M	32 (20)	126 (80)	
	Total	48	169	
Duration of illness				
	0-6month	21(29)	52 (71)	3.8:(1):0.03
	>6month	22 (17)	107(83)	
	Total	43	159	

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Lesion size				
	<4cm2	27(22.5)	93 (77.5)	0.26:(1):0.60
	≥4cm²	17(20)	70 (80)	
	Total	44	163	
CL-type				
	LCL	36 (20)	140 (80)	1.5:(1):0.22
	MCL	12 (30)	29 (70)	
	Total	48	169	
Treatment History	New	43 (21)	161 (79)	2.2:(2):0.3
	Repeat/recurrent	5 (38.5)	8 (61.5)	
	Total	48	169	
Microscopy result				
	P	45 (23)	154 (77)	1.7:(1):0.18
	N	0	6 (100)	
	Total	48	160	

At severe malnutrition, more MCL cases and those patients having a lesion size ≥4cm demonstrate a higher occurrence rate than their counterparts. Interestingly out of the total 48 malnourished cases, 45 (93.75%) were positive [Table 4].

Table 4. Different levels of nutritional status with clinical features of cutaneous leishmaniasis.

Variables	Nutritional status			Total	χ2:(df):p-value
	Sever (%)	Moderate (%)	Normal (%)		
Treatment history					
New	11 (5.4)	32 (15.7)	161(78.9)	204 (100)	2.2(2):0.3
Recurrent	1 (7.7)	4 (30.8)	8 (61.5)	13 (100)	
Total	12	36	169	217	
CL type					
LCL	8 (4.5)	28(16)	140 (79.5)	176 (100)	2.2(2):0.3
MCL	4 (10)	8 (19.5)	29 (70.7)	41(100)	
Total	12	36	269	217	
Lesion size					
<4cm²	3 (2.5)	24 (20)	93 (77.5)	120 (100)	2.5(2):0.2
≥4cm²	5 (6)	12 (14)	70 (80)	87 (100)	
Total	8	36	163	207	
Age					
≤18	3 (3.4)	20 (22.4)	66 (74.2)	89 (100)	14.7(6):0.02
19-40	6 (7.3)	7 (8.5)	69 (84.2)	82 (100)	
41-60	2 (5.8)	4 (11.4)	29 (82.8)	35 (100)	
>60	1 (9)	5 (45.5)	5 (45.5)	11	
Total	12	36	169	217	
Microscopy					
Positive	10	35	154	199	1.7(2):0.4
Negative	0	0	6	6	
Total	10	35	160	205	

2.4. Burden of Cutaneous Leishmaniasis and Malnutrition by Districts

Among the 470 recorded CL patients, nutrition status data were available for 217 individuals. These patients were distributed across 25 districts, with 121 from the South Gondar zone and 96 from the Waghimra zone, which included high CL reporting districts like Dehana and Sekota. These areas also showed a significant prevalence of malnutrition among CL patients, highlighting a concerning

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correlation between malnutrition and the incidence of CL cases. In Waghimra the prevalence of malnutrition among CL cases was higher than South Gondar zone [Table 5, Supplementary Table 1].

Table 5. The burden of malnutrition and concomitance of CL across districts and Zones.

Zone: Administrative area	Number of CL reporting districts	Case number		Total CL cases (Not screened for nutrition)
		CL: Malnourished	CL: Normal for nutrition	
South Gondar	17	16 (11.7%)	121 (88.3%)	354
Waghimra	8	32 (25%)	96 (75%)	116
Total	25	48	217	470

2.5. Cutaneous Leishmaniasis Chronicity and Associated Factors

In the first six months of illness (post-CL lesion), only 29% of children ≤18 sought medical care but older people had a better number to see the hospital for treatment. Larger lesions increased over time, (≥4cm²), from the initial time of the first 6 months, 14 (17.5%) rising to 52 (65%) after six months. All moderate and severe nutrition problems were observed in the first year of infection, rather than longevity of the disease [Table 6].

Table 6. Chronicity and associated factors of cutaneous leishmaniasis.

Variables	Onset of disease/chronicity/time of first visit (month)					χ2:(df):p-value
Month	0-6 (%)	7-<13(%)	13-24(%)	>24 (%)	Total	
Age						
≤18	25 (29)	52 (60.5)	4 (4.5)	5 (6)	86 (100)	14 (9) 0.1
19-40	34 (46)	37 (50)	2 (2.7)	1 (1.3)	74 (100)	
>40	13 (31)	23 (54.7)	1 (2.3)	5 (12)	42 (100)	
Total	72	112	7	11	202	
Nutrition status						
SAM	5 (50)	5 (50)	0 (0)	0 (0)	10 (100)	6.4 (6) 0.3
MAM	16 (48.5)	16 (48.5)	1 (3)	0 (0)	33 (100)	
Normal	51 (32)	91 (57)	6 (4)	11 (7)	159 (100)	
Total	72	112	7	11	202	
Lesion size						
<4cm²	56 (48)	57(49)	0 (0)	3 (3)	116 (100)	28 (3) 0.0001
≥4cm²	14 (17.5)	52 (65)	6 (7.5)	8 (10)	80 (100)	
Total	70	109	6	11	196	

3. Discussion

In our study involving 217 patients with CL and also assessed for nutrition, the result showed that, malnourished individuals had a mean age of 25.5 years, while nutritionally competent patients were 27.2 years, demonstrating a significant link between age and nutritional status ($\chi 2$: 9.8; $p<0.05$). When we see the relationship between sex and CL burden, males are more significantly affected by CL disease, consistent with previous findings [18,19].

Our study revealed that patients with cutaneous leishmaniasis (CL) seeking treatment within 0-6 months demonstrated a higher malnourishment rate (29%) compared to those who came after 6 6-month time period (17%). This could suggest those individuals having a poor nutritional baseline might be more susceptible to the infection of *leishmania* and fast to develop the disease symptoms or in early infection the body triggers energy-intensive processes to respond through innate immunity and cascade to the next level, all these processes may lead to malnutrition, and this fact by itself again may expose the host for disease by weakening the immune system, response, allowing faster infection and possibility of spread [1,20].

Notably, 27% of those aged ≤ 18 were malnourished, and 41% of the disease burden was found in this age group. The problem is attributed to nutrition-related facts. Our finding was supported by

 doi:10.20944/preprints202408.0967.v1

a study in Ethiopia [21], according to this study, the BMI measurements showed that approximately 29% of adolescent girls aged 15-19 were found to be underweight (BMI <18.5). In addition, the prevalence of stunting among children under 5 years old was reported to be 40% in Tigray and 42% in Amhara regions of Ethiopia [22]. These nutritional deficiencies could potentially serve as a foundational factor contributing to the increased incidence of CL at younger ages. This finding is consistent with previous studies conducted in Tigray, north Ethiopia [23], and Addis Ababa, central Ethiopia [24], which also found a higher prevalence of CL in individuals under the age of 18 years.

Our research revealed that 27% of females were CL patients, a bit lower than the study in Gayint, the female patients were 36.8%, and this could be the methodological difference used to conduct the research. In Gayint, an active case finding and referral system was deployed, which may increase the number of female patient s' [25].

The study reveals that 22% of CL patients are malnourished, raising serious concerns and echoing findings from South Ethiopia and Amhara [26,27], the prevalence of malnutrition in older groups of those regions was lower at 17.1% and 17.6% respectively. This discrepancy underscores the need for further research and interventions to address malnutrition among CL patients. Likewise, a study on nutritional status in adults by Abdu et al. 2019 from Harari, Ethiopia [28], reported a prevalence of 15.7%. A similar study with us conducted on American Tegumentary Leishmaniasis [17], found that 10% of patients had low body weight and 12% had hypoalbuminemia. Of course, this might be explained by economic and genetic differences. In a nutritional study of school-age children in the South Gondar Zone, (which was one of our study areas) stunting was prevalent in 11% of children, wasting in 6.3%, and 11.4% were underweight [29]. This tells us that, malnutrition fact could contribute to the finding we see now. Hence, in our study of CL, patients aged ≤18 years, 22.4% were moderately malnourished and 3.3% were severely malnourished. These findings suggest that *Leishmania* infection may take advantage of malnutrition to progress to disease. In regions with high rates of malnutrition and endemic *leishmania*, the incidence of CL might remain elevated.

In areas where malnutrition was common, the burden of CL was also high. Especially in Dehana, Sekota, and Gazgibla districts [Supplementary Table 1]. These findings suggest that malnutrition may contribute to the increased burden of CL in these regions. In the Waghimra Zone, the prevalence of malnutrition was high. According to a study conducted by [30], the host's nutritional status plays a crucial role in protecting against leishmaniasis. The disruption of the host's defense system due to malnutrition can lead to the development of severe disease types. This study suggests a potential link between malnutrition and the prevalence of the cutaneous leishmaniasis parasite. Our research indicated a higher concentration of CL cases in regions with elevated levels of malnutrition [Supplementary Figure 1]. Our study area was an intervention for the Seqota declaration by 2030 aimed to end stunting [22], is focused in Waghimra and part of South Gondar and nearby districts. So, the finding revealed a concerning link between malnutrition and the incidence of CL. This indicates that the nutrition problem in these areas may contribute to a higher incidence of leishmaniasis now and in the future.

Previous research supports our findings, suggesting that the intensity of leishmaniasis can be influenced by factors such as body mass and micronutrient availability in the blood [31]. A study conducted in South Ethiopia further corroborated the relationship between nutrition and CL, showing a 5.8% increase [31], for the occurrence of leishmaniasis in populations below 18 of BMI. Overall, denotes the importance of addressing malnutrition in CL-endemic areas, as improving nutrition could potentially help reduce the incidence of this neglected tropical disease. Very similar to this, a study conducted in various regions has indicated a direct correlation between poverty and the prevalence of leishmaniasis [32]. Further research has shown that higher levels of poverty in certain Indian provinces are linked to an increased incidence of the disease [33]. This can be attributed to the impact of malnutrition on the immune response of the host, thereby facilitating the development of leishmaniasis. Malnutrition has been found to disrupt immune protection by favoring the production of anti-inflammatory prostaglandins over pro-inflammatory cytokines [34]. Additionally, various risk factors such as poverty and malnutrition have been identified as influencing the occurrence of leishmaniasis in affected populations [3].

 doi:10.20944/preprints202408.0967.v1

Nineteen percent of clinical cases of CL were MCL type, with 30% malnutrition. In contrast, LCL type 81%, out of that 20% were malnourished, suggesting that malnutrition's influence on CL type of the disease. This finding is substantiated by related studies, which vivid that how malnutrition aggravates the disease to severe form as well as the pro-inflammatory response generated by the Th1 model diminished and the prof-inflammatory type promoted [30,34], all these phenomena could lead to the modification of clinical polymorphism for CL.

A study revealed that low weight and hypoalbuminemia are correlated with mucosal leishmaniasis [17], suggesting that these factors can hinder the healing of skin lesions and the involvement of mucosal membranes in CL infection. , this finding coincides with ours, more MCL cases were malnourished than the LCL type. Our data also indicates that in CL cases, those living in severe malnutrition conditions had larger lesions compared with smaller lesions. All the previous studies and our findings suggest that malnutrition has the potential to exacerbate lesion size, leading to an increase in mucosal leishmaniasis cases and a latter effect in treatment response.

A comparison of the distribution of different clinical forms of CL disease with other research indicates that the MCL type of the disease was 20.9% [25], in our finding it was 19% the MCL which is consistent. Other studies in Northwest Ethiopia [35], reported MCL case burdens were 13.6% and 15.3% [36], respectively. Suggesting varying prevalence rates in different geographical regions or differences in populations living with higher rates of malnutrition might be the leading reason. A systematic analysis [37], of RNA viruses in Leishmania isolates found no significant association between viral presence and the clinical type of CL disease. Our study shows that malnutrition indicates the link and is a contributing factor to the differences in clinical presentations for CL disease types. To substantiate the connection of the two factors, a study in the United States solidified that, MCL has been linked to malnourishment in patients at a significantly higher rate compared to non-malnourished individuals [38]. Studies have shown that nutritional factors play a role in the outcome of leishmania specious infection [39], with protein-calorie deficiency and deficiencies in trace elements or vitamins being common in affected individuals [39,40]. However, the efficacy of zinc supplementation in CL patients remains inconclusive, with some studies showing no significant difference in treatment response between supplemented and non-supplemented individuals [41]. Overall, protein-energy malnutrition can impact wound healing, but nutritional supplementation with protein-rich oral supplements has been shown to improve healing outcomes [42].

In our study, 64% of CL patients experienced over 6 months of undiagnosed disease, similar to South Ethiopia's 77% [43]. Delays stem from a lack of awareness, traditional beliefs, and fear of stigma, which hinder them from seeking timely treatment [41–43]

This study revealed, about 38.5% of CL patients who had a previous ant-leishmania treatment were malnourished, larger than the new CL case. Studies on malnutrition and treatment indicated that it hinders the treatment outcome by negatively affecting the absorption and nutrient utilization [15]. So in areas where a high prevalence of malnutrition, resulting in higher rates of retreatment and disease circulation [30].

4. Materials and Methods

a. Study area and period

This research was conducted at Leishmaniasis Treatment Centers (LTCs) in Tefera Hailu Memorial Hospital and Addis Zemen Primary Hospital in Amhara region, Ethiopia.

b. Study design, period, and data collection

A retrospective cross-sectional study was conducted from June to July 2024. Those patients of Cutaneous Leishmaniasis (CL) patients were diagnosed and treated in the respective hospitals, January 2023 to May 2024. Data collection utilized a specifically designed checklist for this study and demographic and clinical data were collected.

c. Source population

The source population consisted of patients who were treated for any medical care at the study hospitals, January 2023 to May 2024.

 doi:10.20944/preprints202408.0967.v1

d. Study population

The study population was confirmed CL patients who were treated at the study hospitals between 2018 and 2022 and have complete information in the patient registration logbook.

e. Inclusion and Exclusion criteria

Inclusion: All CL patients confirmed positive through either microscopic diagnosis or clinical diagnosis and at the same time having a nutritional assessment were included in the study.

Exclusion: Patients who were under 6 months of age and adults with a known comorbidity were excluded from the study.

f. Diagnosis of CL cases

Parasitological diagnosis of the leishmania parasite was done through microscopic investigation of the amastigote stage of the parasite using a 10% Giemsa stain and clinical evaluation was also conducted by experienced staff for those negative cases.

g. Determination of nutritional status of CL cases

Nutritional assessment is essential for evaluating malnutrition, particularly using mid-upper arm circumference (MUAC) in children aged 6-59 months and pregnant/lactating mothers. In children aged between 6-59 months a value below 115 mm indicates severe acute malnutrition (SAM), 115-124 mm indicates moderate acute malnutrition (MAM), while 125 mm and above is considered nutritionally normal [16,18].

In screening for malnutrition among adolescents and children (6-18 years), Z-scores indicate BMI deviations from age- and sex-specific medians. A Z-score of 0 signifies the median, while scores below and above indicate malnutrition status: <-3 indicates severe malnutrition, -3 to -2 is moderate, -2 to +1 indicates normal nutrition, and >+1 suggests overweight or obesity [16,18].

The pregnant and lactating mothers were evaluated for malnutrition using the MUAC technique. A measurement of <190mm indicates severe malnutrition, while a measurement between 190-229mm is considered moderate and a measurement of ≥230mm is classified as normal [16,18].

The fourth technique involves screening adults through Body Mass Index (BMI), calculated as weight in kilograms divided by height in meters squared (BMI = weight (kg) / height^2 (m)). BMI classifications include severe malnutrition (SAM) for <16, moderate malnutrition (MAM) for 16-18.5, normal for 18.5-24.9, and overweight/obese for ≥25 as indicated by [16,18].

h. Data management and analysis

The registration logbook data was summarized in Excel, cleaned, and transferred to SPSS version 23 for analysis. Chi-square (Fisher exact tests were performed) to evaluate the occurrence of values between observed and expected proportions. Statistical significance was declared at $p<0.05$.

Operational definition:

- Clinical polymorphism: It is referring the CL patients, the lesion site/ where the lesion was found, and based on that classifications are made as Localized, Mucosal, or diffused, and the treatment cycle, as new or repeat.

i. Ethics approval

Ethical clearance and a support letter for the study were obtained from the scientific and ethics review unit of Amhara Public Health Institute (Ref: APHI 03/1691).

5. Conclusion

This study highlights that younger individuals heightened risks of CL and this could be fueled by the reason we observed in effect for malnutrition. Clinical polymorphism and disease severity might be a result of malnutrition.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org. Supplementary Table 1. The distribution and burden of CL by case reporting districts. Supplementary Figure1. Geospatial distribution of CL cases and the occurrence of malnutrition.

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Supplementary Table 1. Distribution of CL in case reporting districts

Sr. Number	Districts	Malnourished + CL	Only CL	Total case burden	Zone
1	Abergela	1	2	3	Waghimra
2	Addis Zeman	1	4	5	South Gondar
3	Andabet	0	2	2	South Gondar
4	Bahirdar	0	1	1	West Gojjam
5	Debrtabour	2	12	14	South Gondar
6	Dehana	10	28	38	Waghimra
7	Ebnat	1	22	23	South Gondar
8	Enfiraz	0	1	1	South Gondar
9	Estia	2	14	16	South Gondar
10	Farta	4	18	22	South Gondar
11	Fogera	0	2	2	South Gondar
12	Gayent	2	5	7	South Gondar
13	Gazgibla	7	12	19	Waghimra
14	Guna	2	6	8	South Gondar
15	Gunabegmdir	0	1	1	South Gondar
16	Janamora	0	1	1	North Gondar
17	Kimirdengay	0	1	1	North Gondar
18	Lalibela	0	1	1	North wollo
19	Lebokemkem	1	10	11	South Gondar
20	Mekanysus	0	1	1	South Gondar
21	Mekanysus	0	1	1	South Gondar
22	Meketiwa	0	2	2	South Gondar
23	Sehala	0	2	2	Waghimra
24	Sekota	10	15	25	Waghimra
25	Semada	0	2	2	South Gondar
26	T/Gayent	0	1	1	South Gondar
27	Telemit	1	0	1	North Gondar
28	Tsagibji	0	1	1	Waghimra
29	Ziquala	3	2	5	Waghimra
Total		48	169	217	

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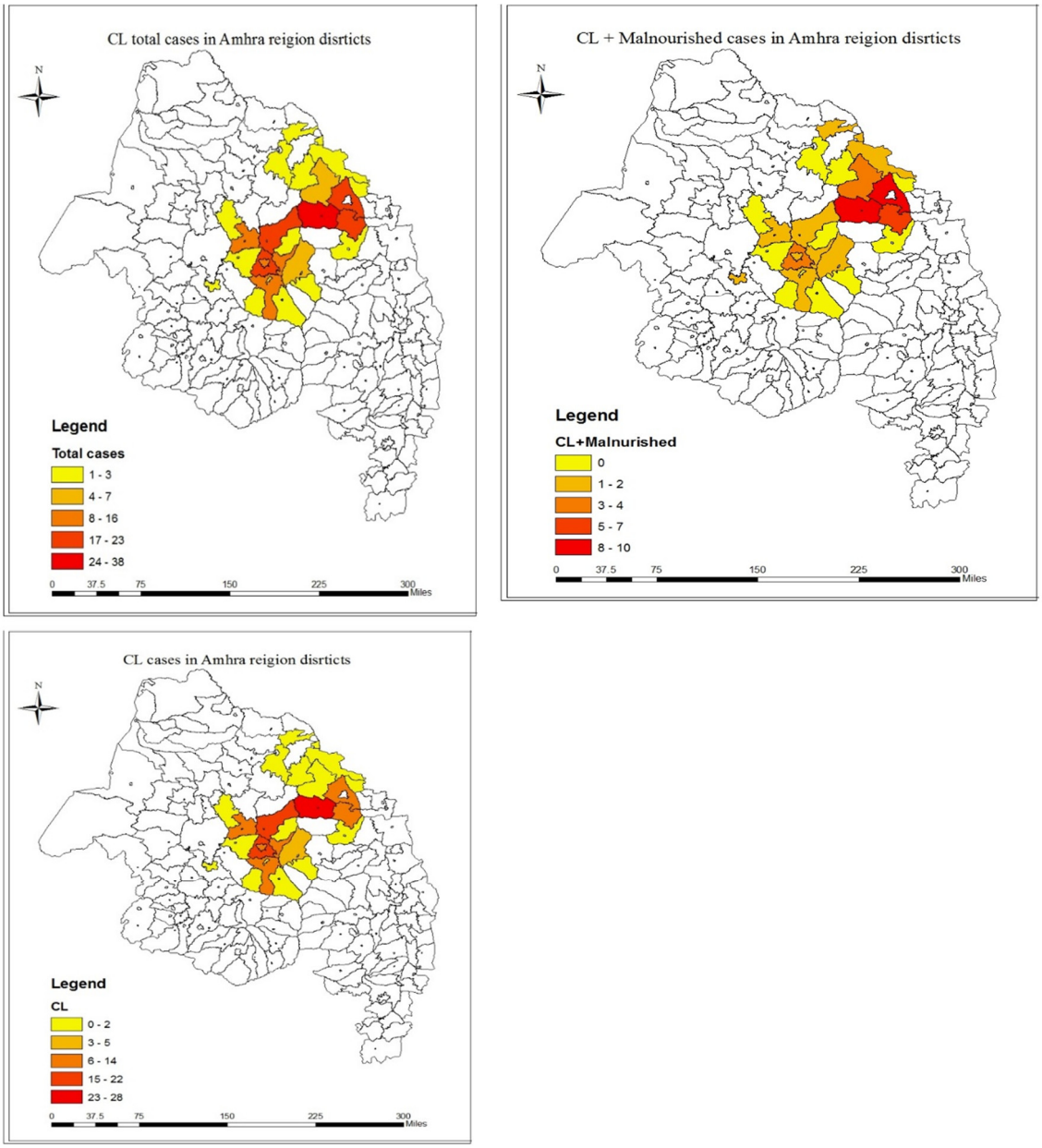

Supplementary figure 1: Geospatial distribution of nutritional status and CL occurrence.

Author Contributions: Conceptualization, methodology, formal analysis, writing original draft BG; Conceptualization, methodology, formal analysis EY; Methodology designing and review and editing EN. All authors read and approved the final version of the manuscript

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Data Availability Statement: Any data related to this research will be available upon request from the corresponding author (It is kept, for the purpose of confidentiality.)

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Conflicts of Interest: The authors declared that they have no competing interests.

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