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Research article

Food security and child malnutrition in the regions of Maradi, Tahoua and Tillabéri in Niger: The status, the causes, and transformative change

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Abstract: This research was undertaken in the agropastoral regions of Maradi, Tahoua and Tillabéri in Niger. The first study covered 900 households and assessed farmers production methods, income, household expenditure, gender issues and food security using four different indicators. The second study assessed causes for child malnutrition by combining a household survey (450 households) with measurement of the upper arm circumference of 1618 children aged 6 to 59 months from these households. A logistic regression analysis was used to identify the causes for malnutrition. The number of food-insecure months in the households were on average 3.54 months per year and 11.4% of the children belonged to the group defined as suffering from 'global acute malnutrition'. Cereal yields were below 250 kg ha^{-1} and only 33% of the households were able to sell any of their cereal harvest. The households spent 66% of their total expenditure on the purchase of food. Money spent on diversifying their nutrition was very limited and horticulture production focused on temperate crops. The indicators for nutrition diversity, food quality and household perception of food security were low. The major causes identified for food insecurity and child malnutrition were low agricultural production, low nutritional diversity, women's autonomy in agriculture (control over income) and poor sanitation. To address these challenges, we propose a mix of incremental and transformative changes, including strengthening the role of women, promotion of precision farming, nutrient-sensitive agriculture, eco-sanitation, and training on improved nutrition and childcare.

Keywords: food production; food diversity; food security; child malnutrition; gender issues; transformative change

1. Introduction

Niger is Sahelian country with a population of over 24.2 million and an annual demographic growth of 3.9 percent - the highest in Africa. Approximately 12.5 million people are under the age of 18 years [2]. Niger is the poorest country in the world according to the Human Development Index, ranking 189 of 189 countries. The World Food Program (WFP) estimated that 20% of the population cannot meet their foods needs in a normal year, while in a drought year this number increase to 30% [2]. WFP 2020 estimated that 10.7% of children from 6 to 59 months suffer from acute malnutrition, and the level of chronic malnutrition in the same age group is 45.7%. According to UNICEF, 48% of children are stunted due to malnutrition [1]. The main consequences of chronic malnutrition include low resistance to infectious disease, blindness, reduced learning capacity, and mental retardation [3].

This alarmingly high level of food insecurity and malnutrition has not changed much in recent decades, despite initiatives by the Nigerian government and the international community [1,4]. When analysing the causes for food insecurity and malnutrition, it is useful to separate between the direct (proximate), intermediate and underlying (ultimate) causes [4]. The direct causes for child malnutrition and child mortality are poor nutrition and infectious diseases. The intermediate causes are poor food supply in terms of quantity and quality, poor childcare practices, inability to provide high quality food for children and health factors connected to low access to health services, inadequate public health services and poor sanitation [4,5]. Only a very low proportion of new-born children in Niger are exclusively breastfed during the first 6 months of life, as recommended by the WHO [4]. The underlying causes are poverty, low income, gender relations, status of the household, low education level and traditional beliefs. A poor family may find it difficult to give particular attention to a weak child as this can reduce the possibility for the other children of the family to survive. Selling production assets to generate cash for saving weak children is also not an easy choice, as this may jeopardize the possibility to provide food for the rest of the family [6]. Population growth, land degradation and weak markets are additional underlying causes [2,7]. The situation is further aggravated by the high level of insecurity in rural areas in Niger as well as the COVID-19 pandemic. Emergency interventions typically address the direct causes for malnutrition, while development-oriented operations address the intermediate and underlying causes for malnutrition.

To address food insecurity and malnutrition, studies highlight the importance of building the absorptive, adaptive, and transformative capacities of households on nutrition [7,8]. Absorptive capacity refers to the ability of the households to make adjustments (such as number of meals served per day) that enable the household to cope with adverse conditions, while adaptive capacity refers to the households' ability to make changes to their food systems, for example cropping systems, to reduce vulnerability to drought. Transformative capacity is defined as the ability of the household to make fundamental changes in the livelihood strategies of the household. The building of assets and the development of safety nets has also been found to build the resilience of households [9].

As shown above, the low level of security and child malnutrition is well documented in Niger, but the relationship between household characteristics, food security and child malnutrition is clearly a research gap. There is furthermore a need to identify low-cost solutions that can address the dire food

security situation.

The objective of this paper is to assess the status of food security and child malnutrition in Niger and to identify the factors causing food insecurity and child malnutrition in regions of Maradi, Tahoua and Tillabéri. Finally, based on the findings, we propose interventions to address these development challenges.

2. Materials and methods

The study was undertaken in the agro-pastoral areas of the Maradi, Tahoua and Tillabéri regions of Niger. The rainfall in these areas is between 400 and 600 mm per year. The Haoussa ethnic group dominates in the regions of Tahoua and Maradi (85%) whereas the Zarma is the main ethnical group in Tillabery (67%). Around 30% of the heads of the households studied were illiterate.

Figure 1. Map of Niger showing the regions. Source: www.worldatlas.com/maps/niger.

This article is based on two studies. The first study was a household survey that assessed livelihood conditions in 900 households in three regions. The second study was a household survey that included 450 households randomly selected from households included in the first survey and

measurements of malnutrition rate of the children in these 450 households (see method below). Prior to starting the surveys, the informants were informed about the objectives of the study, and they were informed that their participation was voluntary.

The first study, which was undertaken in the Tillabéri, Tahoua and Maradi regions during 2016/2017, assessed farmers production practices, male and female headed households' access to production resources, household income and expenditure, and food security. The households' food security and access to nutritious food were examined using various indicators (see below). In each region, 5 communes were identified and from these communes 5 villages were selected. From each village, we randomly selected 10 male household heads and 2 female household heads. This represent between 10 and 20 % of the number of households in the surveyed villages and this can be considered as an acceptable number based on previous knowledge on the variability between the household in similar villages. This gave 300 households per region and a total sample of 900 households. The households selected were from the agro-pastoral zones in these three regions. The villages selected were included in CARE's project "Research and development for improved food security and adaptation to climate change" (REDSAACC).

The indicators used to assess food security in the first survey included the number of food insecure months per year, Household Dietary Diversity Scores (HDDS), Household Food Insecurity Access Scale (HFIAS), and the Food Consumption Score (FCS). These four indicators were used to get a more complete picture of the food security situation as they provide information about access to food, quality of food and household perceptions on food security. The number of food insecure months was assessed directly by asking the head of household to give his/her assessment. HDDS is an indicator assessing diversity of nutrition [10] and is based on a 24-hour recall of food items consumed from 12 different categories. The score can vary from 1 to 12, with a score as close to 12 as possible being preferable. The HFIAS indicator measures uncertainty regarding food supply, perceptions of food quality and insufficient food intake [11]. This score ranges from 0 to 27, and the score should be as close to zero as possible. The FCS is an indicator for food diversity and food quantity. The indicator is based on households' recall of food consumption from eight different food groups during the last seven days [12]. Each food group is weighted according to the importance of the food group for nutrition. The scale for this indicator ranges from 0 to 121. A household with a score below 28 is considered as severely food insecure, between 28 and 52 as moderately food insecure, between 52 and 80 as food insecure and above 80 as food secure. This indicator has been found to capture the variation in diet quantity and quality at an acceptable level in DR Congo [13].

The objective of the second study was to assess the status of child malnutrition and to identify its causes in the regions of Maradi, Tahoua and Tillabéri (data collected from November to December 2019). This study included a survey of 450 households (randomly selected from the 1. survey) and measurement of the upper arm circumference of children in the households to assess acute child malnutrition. In each household, we interviewed the head of household (mostly men) and the spouse separately. In a few cases, we interviewed a female head of household and another male member of the household.

Child malnutrition was assessed by measuring the upper arm circumference of 1,618 children (selected from the 450 households) aged 6 months to 5 years. This represented an average of around 3 children under 5 years per household. Boys constituted 51.4% of the overall sample, whilst 48.6% were girls. Children whose left arm circumference was less than 115 mm were characterized as having *severe acute malnutrition* (SAM), while a child was assigned to the group *moderate acute*

malnutrition (MAM) when the arm circumference was between 115 and 124 mm. *Global Acute Malnutrition* (GAM) is the sum of SAM and MAM. These recordings were taken by enumerators trained on doing these types of measurements.

A logistic regression analysis was undertaken to identify the factors that cause child malnutrition. This method was used because the independent variables were binary in nature. The data were analysed using STATA software, using a 95% level of significance.

3. Results

This chapter presents the data on food production, income generation, gender issues in production, status of food security, level child malnutrition and causes for child malnutrition in the regions of Maradi, Tahoua and Tillabéri.

3.1. Food production, income generation and gender issues

Agriculture is the dominant economic activity in the agro-pastoral areas in three regions. Additional economic activities are livestock production, horticulture and fruit production, and small businesses (Table 1). The results presented here are based on the first survey.

Rainfed crops were practiced by 99.1% of the farmers, and the annual crop area was an average of 5.25 ha per farm. Pearl millet cultivation occupied 44% of the area for annual crops. The average yield of millet and sorghum in the three regions was only 250 kg ha^{-1} and 100 kg ha^{-1} respectively. Production of rain-fed crops is declining according to 57% of producers, while less than 10% think that their production tends to be increasing. Only 14.7% of the households used improved varieties in rainfed production. Mineral fertilizer was used by 23% of the households. The farming operations were mostly conducted manually, with only 0.56% of the farmers possessing a planter. Approximately 66% of the respondents were not selling their rain-fed production, which is an indication that their cereal production is not sufficient.

Livestock was the second most important economic activity after rainfed production. Livestock production in the project areas is semi-sedentary, with animal fattening being prevalent as there is a good market for livestock products related to Islamic celebrations. Whilst most of the farms studied had animals, livestock possession was low with an average of 3 goats, 2 sheep,1 cattle, 2 poultry and 1 guinea fowl per farm. Poultry and guinea fowl production was under the control of women. The average value of the animals was estimated at 320,000 FCFA per household.

Around 63% and 65% of the households in Tahoua and Tillabéry respectively practiced horticulture while in Maradi this was practiced by only 7%. Onion was cultivated by 37% of farmers, cabbage by 11% and tomatoes by 11%. Temperate crops therefore dominate horticulture production in all of the regions, while the production of horticulture crops with a high nutritional value, such a green leafy vegetables and yellow fleshed sweet potato, was very low. Income generated from horticulture per household in Maradi, Tahoua and Tillabéri was 9173, 630,192 and 128,883 FCFA respectively (Table 1). Onion production is the major income generating activity in Tahoua.

Table 1. Average household income (FCFA) from different economic activities in the regions of Maradi, Tahoua and Tillabéri in Niger (1 Euro = 656 FCFA) (based on data 1. survey).

	Maradi	Tahoua	Tillabéri	Average
Horticulture	9173 ± 5623	630,192 ± 130,700	128,883 ± 32,990	256,083 ± 48,230
Rainfed agriculture	41,843 ± 11,250	31,004 ± 7735	217,056 ± 38,420	96,635 ± 14,670
Fruits production	3349 ± 3336	14,358 ± 16,950	18,040 ± 11,720	11,916 ± 6963
Livestock	159,007 ± 62,760	385,937 ± 85,730	423,996 ± 96,890	322,980 ± 48,480
Non-agriculture income	80,535 ± 41,630	174,938 ± 70,300	70,094 ± 24,920	108,522 ± 28,610
Total revenue	293,908 ± 78,220	1,236,430 ± 205,800	858,069 ± 125,600	796,136 ± 88,110

Households in Tahoua also possessed more material items such as radios, bicycles and furniture compared to the other regions. The average value of material items (including confidence interval) was 64,404 ± 8697, 308,653 ± 60,160 and 114,870 ± 17,690 for Maradi, Tahoua and Tillabéri respectively.

The household survey showed that 89% of the households were led by men in the three regions and the production was generally controlled by men. Women's income generation was low compared to that of men. Men controlled 85% of the area under rain-fed crops and 72% of horticultural plots. More than 90% of fruit production sites were also controlled by men. The average income from horticulture for men was 243 000 FCFA compared to 13,000 FCFA for female-headed farms. The income generation activity (IGA) outside of agriculture is also more important for men than for women, with an average income for men of 317,000 FCFA compared to 169,561 FCFA for women. The percentage of women who engaged in IGA was 38%, while the corresponding number for men was 46%. The main IGA of women was the sale of biscuits in local markets.

3.2. Food security, food diversity and household expenditure

The food security situation was assessed using the indicators: number of months of food insecurity per year; Household Diversity Scores (HDDS); Household Food Insecurity Access Scale (HFIAS); and the Food Consumption Score (FCS). These indicators give an overview of the situation in the households regarding food security, diversification of food, quality of nutrition and the households' perceptions of food quality and access to food.

Table 2. Indicators of food security in the regions of Maradi, Tahoua and Tillabéri (based on data 1. survey).

Regions	Number of food insecure months	Household Dietary Diversity Score	Household food insecurity access scale	Food consumption score
Maradi (n = 300)	4.03 ± 0.32	4.59 ± 0.25	9.67 ± 0.75	43.21 ± 2.25
Tahoua (n = 300)	2.71 ± 0.27	6.21 ± 0.27	7.45 ± 0.58	54.32 ± 1.82
Tillabéri (n = 300)	3.88 ± 0.33	5.43 ± 0.21	10.22 ± 0.70	43.67 ± 1.83
Average (n = 900)	3.54 ± 0.18	5.41 ± 0.14	9.12 ± 0.40	47.07 ± 1.19

The average number of food insecure months per year was 3.54, but there were significant differences between the regions (Table 2). In Tahoua, the number of food insecure months was 2.7

while households in Tillabéri and Maradi were food insecure for around 4 months. The HDDS, which measures food diversity, was in average 5.41. This is far below the maximum score of 12. Maradi had the lowest score for this indicator, whereas Tahoua had the highest. The FCS, which is a measurement of the quality of nutrition, was also lowest for Maradi and Tillabéri. The average score for the three regions was 47.1. Households with a FSC score below 52 are considered to belong to the groups defined as severely or moderately food insecure. Only Tahoua had a score slightly above 52. Households' perceptions on food security and nutritional quality were measured by the HFIAS. Tahoua also performed the best regarding this indicator. The average score across the regions for this indicator was 9.12, which is well below the maximum score of 27.

The study of household expenditure in the first survey also shed light on the food security situation (Figure 2). The households spent 66% of the total expenditure to purchase food. Household expenditure on cereals constituted 49% of the total food expenses. The amount spent on purchasing food with high nutritional value such as vegetables, eggs, milk, and meat was low. The total household expenditure on non-food items was 55110 FCFA, of which 21% was used on health-related expenses.

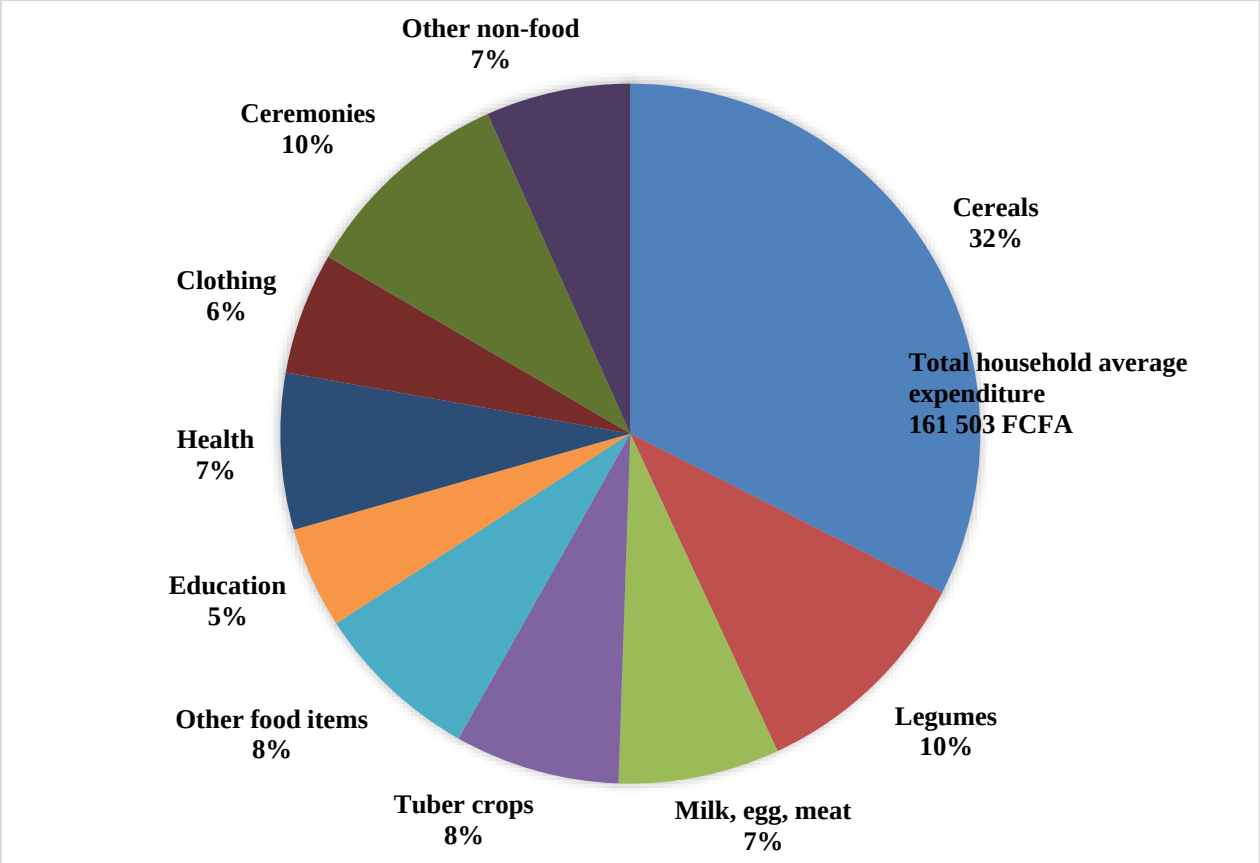

Figure 2. Distribution of household expenditure (based on 1. survey).

Sanitary conditions, access to drinking water and quality of housing also affect food security and child malnutrition. Only 24% of the households had access to latrines and 19% used rudimentary latrines. Access to drinking water appeared to be satisfactory with 98.7% of the households having access to tap water, borehole water or well water. Housing was poor, with 98% of households having earthen floors and only 2.3% with access to electricity.

3.3. Child malnutrition

The survey in the three regions showed that 3.7% of the children suffered from SAM, whereas 7.6% belonged the to the moderate severe malnutrition group (MAM) (Table 3). Furthermore, the level of GAM was 11.4%. There was only a minor variation between the regions regarding child malnutrition, and Tahoua had the highest levels of GAM. Oedema was identified in 7% of the children and 9.3% of the children had been hospitalized for malnutrition. Tahoua had the highest level of children with oedema (9.6%) and the highest level of children hospitalization for malnutrition (11.1%). This data indicates a very severe situation regarding child malnutrition.

Table 3. Child malnutrition of children aged 6-59 months in the regions of Maradi, Tahoua and Tillabéri (based on data from 2. survey).

	Regions							
Variables	Maradi		Tahoua		Tillabéri		Total	
	N = 510	%	N = 531	%	N = 577	%	N = 1618	%
Level of malnutrition								
Severe Acute Malnutrition	20	3.92	14	2.64	27	4.68	61	3.77
Moderate Acute Malnutrition	35	6.86	50	9.42	38	6.59	123	7.60
Global Acute Malnutrition	55	10.78	64	12.05	65	11.27	184	11.37
Other parameters								
With oedema	38	7.45	51	9.60	24	4.16	113	6.98
Already treated in hospital for malnutrition	75	14.71	59	11.11	17	2.95	151	9.33
Malnutrition not treated in hospital	20	3.92	22	4.14	41	7.11	83	5.13

3.4. Factors affecting child malnutrition

The regression analysis showed that child malnutrition was influenced by several factors, and that the factors that significantly influenced the SAM, MAM and GAM were not necessarily the same (Table 4). The interpretation of the results is also made complicated because some of the factors had an opposite effect on SAM and MAM.

The analysis showed that the level of SAM increased with increasing age of the head of household (Table 4). Furthermore, the incidence of MAM was less among Tuareg children compared to Haoussa children. MAM increased with social status. SAM, however, decreased with increasing social status, though this effect was not significant.

There was a significant negative relationship between SAM and women's autonomy in agriculture, which means that severe malnutrition decreased with increasing autonomy of women. This coefficient was also negative for MAM and GAM.

There was a negative relationship between the possession of material items and MAM, i.e., child malnutrition was less for households with more material items. Furthermore, there was a negative relationship between weak control over income and SAM. There was a positive relationship between leisure time and MAM. In addition, there was a positive relationship between oedema, SAM and GAM.

Oedema is therefore a reliable indicator for malnutrition. There was no effect of the regions on malnutrition.

Table 4. Logistic regression to determine factors affecting Severe Acute Malnutrition (SAM), Moderate Acute Malnutrition (MAM) and Global Acute Malnutrition (GAM) of children aged 6 to 59 months in the regions of Maradi, Tahoua and Tillabéri in Niger (the first alternative of the variable has the value of 1 and the second value of the variable has has the value of 0) (based on data from 2. survey).

Variables	SAM	MAM	GAM
Male or female	0.256	1.139	0.996
Age of head of household	−0.002	0.024*	0.016
Ethnic Zarma or Haoussa	−0.868	−0.341	−0.335
Ethnic Peulh or Haoussa	0.334	−0.183	0.351
Ethnic Touareg or Haoussa	−0.281	−1.337*	−0.938*
Ethnic Gourmantché Haoussa	0.318	−0.853	−0.247
Analphabet or alphabetized	−0.232	−0.441	−0.319
Agriculture as main activity	−0.001	1.638	0.754
Social status (leader)	−0.663	1.567***	0.741*
Able to make decisions on agriculture	0.000	−1.113	−1.798
Women's autonomy in agriculture	−1.156*	−0.276	−0.470
Material possessions	0.229	−1.195*	−0.545
Right to use material belongings	0.344	−0.253	−0.203
Right to take up credit	−0.778	0.047	−0.069
Weak control over the use of income	3.379*	1.435	2.341
Member of organisation	0.031	−0.088	−0.019
Speaks in public	0.142	0.504	0.488
Leisure time	−0.339	0.840**	0.385
Signs of oedema	2.133***	0.375	0.996**
Accessible village	−0.204	−0.044	−0.143
Tahoua or Maradi region	0.451	0.521	0.507
Tillabéri or Maradi region	0.990	−0.137	0.033
Constant	−2.000	−6.426***	−3.934***
Log likelihood	−115.61	−190.78	−234.81
LR chi2(21)	37.22	74.28	54.30
Prob > chi2	0.0159	0.0000	0.0001
Pseudo R^2	0.14	0.16	0.10

4. Discussion

4.1. Food production, income generation, gender issues and food security

The study showed that agricultural productivity is very low and that production to a large degree is controlled by men, even horticulture production. Furthermore, horticulture is generally oriented toward producing cash crops, and its contribution to improving nutrition is very limited.

The study showed that food insecurity and child malnutrition are key development challenges in Niger. The indicators "number of food insecure months", HDDS, FCS, and HFIAS, measuring food availability, food diversity, nutritional quality and household's perception of food quality and food security, were low in all the regions. The households were food insecure for an average of 3.5 months per year, though the situation was less severe in Tahoua than in the Maradi and Tillabéri regions. The scores for the indicators "food quality and perceptions of food security" were also better in Tahoua than in the other regions. The average income generated was respectively 0.29, 1.21 and 0.86 million CFA per household. The income generated from onion production was the main reason for the higher income generation in Tahoua. In Maradi, only 7% of the households practiced horticulture due to limited access to water. The indicators Household Dietary Diversity Score and Food Consumption Score which both measure different forms of food diversity showed good consistency in results as both indicators rated food diversity to be significantly better in Tahoua compared to the other two regions.

Household expenditure also shed light on the food security situation. About 66% of the households were unable to sell any of their millet or sorghum production. Instead, they had to purchase food to ensure their survival and 66% of their total expenditure was used on food. Cereals constituted about 50% of the food purchased. This also illustrates that the households are not able to generate a surplus of cereal production. Household expenditure on other types of food was low; purchased food did not, therefore, contribute much to improving the diet. It appears that household income was too low to ensure a diverse diet.

The households were on average food insecure for 2.87 months per year in Tahoua, compared to 4.03 and 3.88 months in Maradi and Tillabéri respectively. This high level of food insecurity is linked to low crop and livestock production. The average yield was 250 and 100 kg ha^{-1} for pearl millet and sorghum respectively. Such low productivity cannot generate a cereal surplus as the average household consisted of 11 people. This yield is very low considering the national average yield is approximately 500 kg ha^{-1} [3].

4.2. Child malnutrition

Child malnutrition was severe in the three regions. The level of general acute malnutrition (GAM) found in this study was 11.4%. For context, WHO consider a value above 10% as alarmingly high. One consequence of child malnutrition is stunting, and 42% of children in Niger suffer from this problem [14].

There are several reasons for high child malnutrition in Niger. The Household Dietary Diversity Score (HDDS) found in this study was 5.4, which means that households only consumed food from 5 out of the 12 food groups. The data on food expenditure and production showed that food consumption is mainly based on cereals. A study on nutrition among pregnant women in the Zinder region of Niger showed that iron, zinc, iodine, folate and vitamins A and B_{12} were the major deficiencies [15].

We found no clear link between household food security and child malnutrition in this study. The survey undertaken in 2017 showed that the scores for the number of food insecure months, HDDS and FCS were significantly better in Tahoua compared to the other regions. The value of material items and household expenditure were by far the highest in this region. However, the score for child malnutrition was not better in Tahoua compared to the other regions. On the contrary, we found that the scores for GAM, oedema and the number of children hospitalized for malnutrition was higher in Tahoua compared to the other regions. The regression analysis also showed no effect of the regions on child malnutrition. Hence, improved food security and increased household income did not translate into improved child nutrition in this study. A study from Malawi and Kenya also showed that increased household income does not necessarily reduce child malnutrition [16].

Child malnutrition may also be connected to the position of women in their society. The survey conducted in 2017 found that women have much less control over production resources such as land than men, and women's income generation is also much less than that of men. The regression analysis showed that severe malnutrition decreased with increasing autonomy of women in agriculture. A positive effect of women's autonomy on child nutrition and health has been shown in another study in Niger [4], where the promotion of income generation activities and the establishment of saving and credit schemes was recommended to strengthen women's control of resources.

Women's poor nutrition may be another explanation for high child malnutrition. A study in the Zinder region of Niger found that only one in six pregnant or breastfeeding women have sufficiently diverse nutrition, and only 50% of women have sufficient food security [17]. The rate of anaemia in pregnant women is 58.7%, and 73% of children under 5 years suffer from this deficiency [13]. In addition, most women in the Zinder region have insufficient weight gain during pregnancy [18]. To address child malnutrition, it is therefore essential to improve the nutrition of pregnant- and breastfeeding women as well as children.

The high level of child malnutrition may also be related to limited access to appropriate sanitation. The baseline study showed that only 24% of the households had access to latrines, and UNICEF have reported that only 26.7% of schools have access to sanitation facilities in Niger [19]. Poor sanitation is likely to cause diarrhoea with severe consequences on food utilization.

The regression analyses also shed light on the reasons for child malnutrition, but the factors that control SAM, MAM and GAM were not consistent in this study. SAM was increased by oedema and women's low autonomy in agriculture. Increasing women's autonomy in agriculture can therefore reduce child malnutrition. For MAM, there was a negative relationship with the right to possessions of durable goods, showing that improved resource control decreased child malnutrition. It is surprising that there is a positive relationship between social status and MAM. However, another study from Niger showed that higher social status does not necessarily translate into improved child nutrition [4]. Child malnutrition was less severe among Tuareg children compared to Haoussa children. Tuaregs have generally high numbers of livestock, and it is possible that Tuareg children have better access to milk.

When interpreting the results of the regression analysis, it important to bear in mind that this analysis particularly addressed the household factors that can explain child malnutrition, while factors external to the household such as access to market, health services and sanitation were not included. A study from neighbouring areas in northern Nigeria using regression analysis between household characteristics and child malnutrition also showed that it is not always easy to establish significant relationships between the variables [20].

A study in Mali also found than child malnutrition was influenced by the resilience capacity of the households in terms of cultivated area, livestock ownership, quality of housing, sanitation, access to electricity, household characteristics and family health [8].

Our findings, combined with literature studies, lead us to conclude that in order to reduce child malnutrition, it is not sufficient to only strengthen the general livelihood conditions of households. Despite higher income and less food insecurity in Tahoua, child malnutrition was not better in this region compared to the other regions studied. Strengthening households' competence on childcare and child/mother nutrition, and improving mother's access to resources should be key components of programs focusing on improving food security and mother/child nutrition.

4.3. Addressing food insecurity and child malnutrition in rural Niger

This study has shown that there are multiple causes of food insecurity and child malnutrition in Niger. Key challenges are low cereal production, limited contribution of horticulture to improve nutrition, lack of diversity in nutrition, inadequate sanitation and women's low autonomy in agriculture. The problems of food insecurity and child malnutrition can therefore best be addressed by a holistic approach spanning agriculture, nutrition, sanitation, health and education. However, the funds for this are limited. It is therefore important to look for cost efficient approaches - or 'low hanging fruit'.

The households were food insecure for an average of 3.54 months and farmers were not able to produce a surplus cereal production. However, there is an untapped possibility to improve rainfed agricultural productivity by introducing new technologies. An animal-drawn multicultivator/planter for the simultaneous application of seeds and micro-dosing of compost/mineral fertilizer has recently been developed for dryland crops in Niger. Use of this planter in combination with a production package consisting of seed priming, micro-dosing of compost/mineral fertilizer increased millet yield by 113%, increased net income by 116%, and reduced labour use during sowing by 86% [21]. This package can make agriculture less vulnerable to climate change due to timelier sowing and shortening the growing period by more than 10 days. A production package based on the mechanized application of seed and fertilizer by planters can be characterized as a simple form of precision farming because it allows for precision in the quantity of input applied, application depth, planting density and timelier farm operations [22]. Improved agricultural technologies can also improve nutrition. A study in Niger by the International Food Policy Research Institute (IFPRI) showed that the introduction of stone bunds for run-off control, tree planting, manure application and integrated soil fertility management increased yields by more than 30%, enhanced per capita caloric intake (8 to 36% increase) and improved household food diversity [23]. Hence, the use of improved technologies can result in a triple-win in terms of increased yield, enhanced food security and improved nutrition. Studies from Burkina Faso and China also indicate that different forms grain banks can also contribute to improve farmers income and food security [24,25].

Low food diversity and child malnutrition were identified as major development problems in the regions studied. Major nutritional deficiencies in the Sahelian countries are in iron, iodine, zinc, foliate, and vitamins A and B_{12} [15]. It is a paradox that these deficiencies can be easily corrected by diversifying the diet using locally produced food. A review of nutrition in low-income countries also showed that an increase in crop diversity and livestock ownership was associated with increased dietary diversity and increased intake of essential micronutrients [26]. We believe that there is a need to reorient the food system towards producing foods that ensure a healthy diet. Our study showed that whilst horticulture is a major income-generating activity, its contribution to improving nutrition is low. In addition, we found that horticulture production is mostly based on the cultivation of temperate crops such as onion, cabbage, and tomato. These crops are grown in the dry, cold season when irrigation is required. This increases the cost of production. We do not argue for a discontinuation of the cultivation of these crops as they are key for income generation, but we think more emphasis should be given to the cultivation of crops of tropical origin that can be cultivated during the warm rainy season. Such crops with a high nutritional value include green leafy vegetables such as African eggplant, *Corchorus tridens*, *Moringa oleifera* and yellow-fleshed sweet potato, rich in vitamin A. The leaves of these crops can also be dried and used to supplement the food when these crops are not available. Development projects often establish communal gardens by digging a well followed by fencing the area. A more

low-cost approach that can ensure improved nutrition is to establish small kitchen gardens at each homestead with the above crops as well as fruit trees such as mango to supply a continuous supply of nutrients throughout the year [27–29]. Rainwater, collection from roofs and spill water from households can ensure irrigation. Small ruminants and particularly poultry can easily be integrated into such kitchen gardens to enrich the diet and provide manure for the garden. Use of biofortified crops such as sweet potatoes with an orange coloured flesh (rich in vitamin A) is another other approach to increase the nutrient content of locally produced food [30].

There appears to be a clear gender dimension in food insecurity and child malnutrition. Our study showed that women have much less control over production resources than men regarding cultivated areas, access to inputs and control over income. In horticulture production, women farmers only receive 5% of the income generated in the sector. Unequal access to production resources is also a problem in Ethiopia. A study showed that women systematically get less access to agricultural extension than men in the country [26]. Women's position in society can be strengthened by improving women's access to production resources and by ensuring women farmers the same access to agricultural extension as men and improving women's access to input. However, this may challenge existing local traditions and norms. A study from 13 countries in Africa using national data on malnutrition also showed that education of women and increasing income for women can improve nutrition even under conditions of climate change [31]. A study from Pakistan also showed a positive effect of women land ownership and women's autonomy in large-scale family purchases on children's food and nutrition security [32].

Finally, poor sanitation was identified as a factor threatening food security, as inadequate sanitation causes repeated illness with severe impacts on child nutrition and health. Eco-sanitation, which includes the collection, treatment and reuse of human excreta, has been promoted in Burkina Faso. The most success was reported in areas where the households were trained on using the compost for increased agricultural production [33]. However, a major challenge related to promotion of Eco-sanitation was the average construction cost (around 180 US$). There is therefore a need to develop simpler and more low-cost solutions along with awareness-raising on improved hygiene.

We have shown that it is possible to improve food security and reduce malnutrition by promoting improved technologies in rainfed production, reorienting and diversifying horticulture production, ensuring women farmers improved access to production resources, and introducing low-cost sanitation measures. The approach proposed here is a mix of incremental and transformative changes to address food security and child malnutrition (Figure 3). The changes proposed are incremental in terms of increasing production using approaches such as seed priming and micro-dosing and emphasizing the production of nutrient-rich food. There is furthermore a need to strengthen the training of households on nutrition, childcare and improved hygiene. It is transformative in the sense of highlighting the need to dramatically strengthen the role of women in rural areas; to focus on nutrition-sensitive agriculture (emphasizing production of nutrient rich vegetables); a shift to precision farming to make agriculture a more attractive business and less vulnerable to climate change; and finally Eco-sanitation. The proposed changes can double cereal yield; significantly reduce labour demand in dryland farming; ensure a continued supply of nutrient-rich food throughout the year; strengthen women's position in society and improve their incomes; and improve health through improved sanitation. This approach can be brought to scale as the investments- and running costs are low.

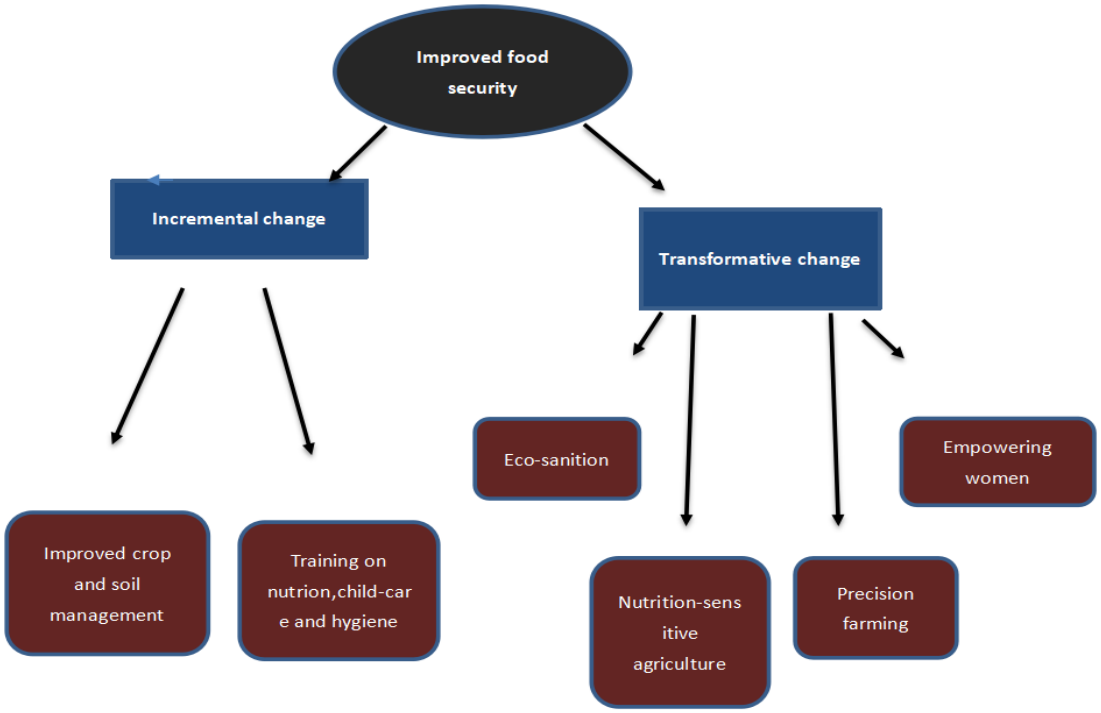

Figure 3. An approach for assessing food security through incremental and transformative changes.

Studying the relationship between household characteristics, food security and child malnutrition is challenging as there are several methodological difficulties. First of all it may be difficult for the households to recall the type of food they have consumed during the last 24 hours and the last week. It will also be difficult for the household to remember their different types of expenses. An addition challenge is that the study is based on the households subjective assessment of their food security situation and the characteristics of their households. Households may also differ in their willingness to share information on the food security and household characteristics. There could also be a gender bias as most heads of households were men and their perceived situation of the food security situation may differ from that of women. Finally, the indicators used to assess food security and nutritional status may not give a complete description of the situation in the household.

5. Conclusion

The study showed that the households in the regions were food insecure for an average of 3.54 months per year and 11.4% of the children suffered from malnutrition (Global Acute Malnutrition). The households had low scores on food diversity, food quality and perceptions on food security and food quality. About 66% of the households could not produce a surplus cereal production, and the households spent more than 66% of their total expenditure on food. Household expenditure to diversify nutrition was very low. The factors that were found to cause low food security and child malnutrition included low agricultural production and income, low diversification of diets, low female control over production and poor sanitation. Our results indicate that improving general household food security and household income will not necessarily reduce child malnutrition. Interventions to improve household nutrition should therefore be combined with target interventions to improve nutrition for

children as well as pregnant and breastfeeding women.

We propose a mix of incremental and transformative changes to address food security and child malnutrition. The incremental changes suggested are related to the use of improved agricultural technologies and to the capacity-building of the households in improved nutrition. Transformative change is promoted by strengthening the role of women in rural areas, emphasizing nutrition-sensitive agriculture, a shift to precision farming and low-cost mechanization, and Eco-sanitation for improved hygiene and compost production. The proposed changes will not only improve food security and nutrition, but will also generate an economic surplus that is critical for improving local livelihoods.

Future research should also focus identifying approaches/technologies that can improve food security and reduce child malnutrition.

Conflict of interest

The authors declare that they have no conflict of interest.

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References

1. UNICEF (2021a) Children in Niger. Available from: www.unicef.org/niger/children-niger.
2. WFP (2021) World Food Program Niger. Available from: www.wfp.org/countries/niger.
3. FAO (2021) Household food security and community nutrition. Micronutrients. Available from: www.fao.org/ag/agn/nutrition/household_micronutrients_en.stm.
4. Hampshire K, Casiday R, Kilpatrick K, et al. (2009a) The social context of childcare practices and child malnutrition in Niger's recent food crises. *Disasters* 33: 132–151. https://doi.org/10.1111/j.1467-7717.2008.01066.x
5. Young H, Jaspars S (2006) Meaning and measurement of acute malnutrition: A primer for decision-makers. Network Paper No. 56. Humanitarian Practice Network. Overseas Development Institute, London. Available from: odihpn.org/wp-content/uploads/2006/11/networkpaper056.pdf.
6. Hampshire K, Panter-Brick C, Pilpatrick K, et al. (2009b) Saving lives, preserving livelihoods: Understanding risk, decision-making and child health in a food crisis. *Soc Sci Med* 68: 758–765. https://doi.org/10.1016/j.socscimed.2008.11.014
7. Dufour C, Kauffmann D, Marsland N (2014) Enhancing the links between resilience and nutrition. In: Fan S, Pandya-Lorch R, Yosef S, *Resilience for Food and Nutrition Security,* International Food Policy Research Institute, Washington DC., 107–117. Available from: ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/128450/filename/128661.pdf.
8. D'Errico M, Pietrelli R (2017) Resilience and child malnutrition in Mali. *Food Secur* 9: 355–370. https://doi.org/10.1007/s12571-017-0652-8
9. Boukary AG, Diaw A, Wünscher T (2016) Factors affecting rural households' resilience to food insecurity in Niger. *Sustainability-Basel* 8: 181. https://doi.org/10.3390/su8030181

10. Kennedy G, Ballard T, Dop MC (2013) Guidelines for measuring household and individual dietary diversity. Nutrition and Consumer Protection Division, Food and Agriculture Organization of the United Nations. https://www.fao.org/3/i1983e/i1983e00.pdf
11. Coates J, Swindale A, Bilinsky P (2007) Echelle de l'accès déterminant l'insécurité alimentaire des ménages (HFIAS) pour la Mesure de l'Accès alimentaire des Ménages: Guide d'Indicateurs (version 3). Projet d'Assistance technique en matière d'Alimentation et de Nutrition, Académie pour le Développement de l'Education, Washington D.C., USA.
12. Wiesmann D, Bassett L, Benson T, et al. (2009) Validation of the World Food Programme's Food Consumption Score and Alternative Indicators of Household Food Security. IFPRI Discussion Paper 00870, Washington DC., 90. Available from: ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/32010/filename/32011.pdf.
13. Marivoet W, Becquey E, Campenhout BV (2019) How well does the Food Consumption Score capture diet quantity, quality and adequacy across regions in the Democratic Republic of the Congo (DRC)? *Food Secur* 11: 1029–1049. https://doi.org/10.1007/s12571-019-00958-3
14. UNICEF (2018) Preventing under-nutrition in Niger. The situation. UNICEF Niger Issue Brief. https://www.unicef.org/niger/media/871/file/ISSUE%20BRIEF%20Preventing%20Stunting%20in%20Niger.pdf
15. Wessells KR, Ouédraogo CY, Young RR, et al. (2017) Micronutrient status among pregnant women in Zinder, Niger and risk factors associated with deficiency. *Nutrients* 9: 430. https://doi.org/10.3390/nu9050430
16. Kennedy E, Peters P (1992) Household food security and child nutrition: The interaction of income and gender of household head. *World Dev* 20: 1077–1085. https://doi.org/10.1016/0305-750X(92)90001-C
17. Wessells KR, Rebecca R, Young RR, et al. (2019) Assessment of dietary intake and nutrient gaps, and development of food-based recommendations, among pregnant and lactating women in Zinder, Niger: An Optifood Linear Programming Analysis. *Nutrients* 11: 72. https://doi.org/10.3390/nu11010072
18. Ouédraogo CT, Wessells KR, Young RR, et al. (2020) Prevalence and determinants of gestational weight gain among pregnant women in Niger. *Matern Child Nutr*, 16: 1. https://doi.org/10.1111/mcn.12887
19. UNICEF (2021b) Water, sanitation and hygiene. Available from: www.unicef.org/niger/water-sanitation-and-hygiene.
20. Amare M, Benson T, Fadare O, et al. (2018) Study of the determinants of chronic malnutrition in Northern Nigeria: Quantitative evidence from the Nigeria demographic and health surveys. *Food Nutr Bull* 39: 296–314. https://doi.org/10.1177/0379572118768568
21. Nourou AI, Saidou AK, Aune JB (2020) Development and use of a planter for simultaneous application of seed, fertilizer and compost in pearl millet production in Niger-Effects on labor use, yield and economic return. *Agronomy* 10: 1886. https://doi.org/10.3390/agronomy10121886
22. Aune JB, Coulibaly A, Giller KE (2017) Precision farming for increased land and labour productivity in semi-arid West Africa. A review. *Agron Sustain Dev* 37: 16. https://doi.org/10.1007/s13593-017-0424-z
23. Nkonya E, Ru Y, Kato E (2018) Chapter 2. Economics of land degradation in Niger. In: Wouterse FS, Badiane O, *Fostering transformation and growth in Niger's agricultural sector,* Wageningen Academic Publishers, the Netherlands, 35–59. https://www.wageningenacademic.com/doi/epdf/10.3920/978-90-8686-873-5_2

24. Li, T, Zhou D, Razzaq A, et al. (2021) Rethinking the role of grain banks in China's agriculture. Agriculture 11: 49. https://doi.org/10.3390/agriculture11010049
25. Delavallade AC, Godlonton S (2020) Locking crops to unlock investment: Experimental evidence on warrantage in Burkina Faso. World Bank Policy Research Working Paper no. 9248. Delavallade, Clara Anne and Godlonton, Susan, Locking Crops to Unlock Investment: Experimental Evidence on Warrantage in Burkina Faso (May 18, 2020). World Bank Policy Research Working Paper No. 9248, https://ssrn.com/abstract=3604697
26. Tsige M, Synnevåg G, Aune JB (2020) Gendered constraints for adopting climate-smart agriculture amongst smallholder Ethiopian women farmers. *Sci Afr* 7: e00250. https://doi.org/10.1016/j.sciaf.2019.e00250
27. Ruel MT, Quisumbing AR, Balagamwala M (2018) Nutrition-sensitive agriculture: What have we learned so far? *Glob Food Secur* 17: 128–153. https://doi.org/10.1016/j.gfs.2018.01.002
28. Galhena DH, Freed R, Maredia KM (2013) Home gardens: a promising approach to enhance household food security and wellbeing. *Agr Food Secur 2*: 8. https://agricultureandfoodsecurity.biomedcentral.com/articles/10.1186/2048-7010-2-8
29. Nwaneke PK, Chude VO (2017) Are the homestead gardens a possible solution to combating malnutrition in Nigeria? *Eur J Nutr Food Saf 7*: 199–208. https://doi.org/10.9734/EJNFS/2017/36520
30. Razzaq, A, Tang Y, Qing P (2021) Towards sustainable diets: Understanding the cognitive mechanism of consumer acceptance of biofortified foods and the role of nutrition information. *Int J Env Res Pub He* 18: 1175. https://doi.org/10.3390/ijerph18031175
31. Davenport F, Grace K, Funk C, et al. (2017) Child health outcomes in sub-Saharan Africa: A comparison of changes in climate and socio-economic factors. *Global Environ Chang 46*: 72–87. https://doi.org/10.1016/j.gloenvcha.2017.04.009
32. Rehman A, Ping Q, Razzaq A (2019) Pathways and associations between women's land ownership and child food and nutrition security in Pakistan. *Int J Res Pub He* 16: 3360. https://doi.org/10.3390/ijerph16183360
33. Dickin S, Dagerskog L, Jiménez A, et al. (2018) Understanding sustained use of ecological sanitation in rural Burkina Faso. *Sci Total Environ* 613–614: 140–148. https://doi.org/10.1016/j.scitotenv.2017.08.251

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