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Dietary profile of school-age children in rural areas of the Madagascar highlands

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Abstract

Malnutrition remains a major public health issue, particularly in low-income countries. Among school-age children (6 to 15 years old), this problem compromises growth and development. In Madagascar, despite high agricultural potential, child malnutrition persists, particularly in rural areas. In response to this issue, the aim of the study is to assess the dietary profile of school-aged children in rural areas of the Vakinankaratra region. It is based on the following research question: to what extent are the nutritional needs of school-aged children met? The hypothesis suggests that energy intake is generally satisfactory, whilst protein and micronutrient intake remains insufficient. A food frequency questionnaire was administered to 269 children from different households. The data were analysed using multiple correspondence analysis, followed by discriminant factor analysis and benchmarking. Three dietary profiles emerged. Class 1 (25%) comprises the most vulnerable households, heavily reliant on starchy foods and characterised by very low dietary diversity. Class 2 (58%), the intermediate group, shows better access to animal proteins but remains deficient in protective foods. Class 3 (16%) comprises the most affluent households, whose diet is diverse. These results highlight significant nutritional inequalities and a persistent reliance on carbohydrate-rich foods, underscoring the need to implement strategies aimed at improving intakes of animal proteins, dairy products, fruit and vegetables.

Keywords: Food Security; Dietary Diversity; Nutritional Requirements; Malnutrition; Madagascar

1. Introduction

Malnutrition remains one of the major public health challenges worldwide. In addition to armed conflicts and socio-economic crises, the effects of climate change are weakening agricultural systems and causing long-term damage to food security, particularly in low- and middle-income countries [1]. Hunger is more prevalent in contexts where a large proportion of the population depends directly on rain-fed agriculture, which is highly vulnerable to climatic hazards [1].

Middle childhood, defined as the period between 5 and 9 years of age, is characterised by relatively stable growth, whilst adolescence is marked by an acceleration in physical and psychosocial development. Several studies highlight that adequate nutrition during these periods can promote catch-up growth in children who have suffered from early stunting, with potential benefits for cognitive performance and long-term health [2]. These phases are also key periods for the acquisition of sustainable eating habits [2].

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However, data on the nutritional status and dietary practices of school-age children remain limited, particularly in low-income countries. The few available studies indicate that diets in 15 rural areas are predominantly dominated by cereals, roots and tubers, with insufficient consumption of foods rich in micronutrients such as fruit, vegetables and animal products [3,4]. This situation is particularly worrying, as eating habits acquired during childhood tend to persist into adulthood [2].

In Madagascar, despite significant agricultural potential, malnutrition indicators remain high, particularly in rural areas. Children and adolescents there face multiple constraints: limited economic access to nutritious foods, geographical isolation, seasonal dependence on markets, and social norms influencing the intra-household distribution of food resources [5].

In light of this issue, the objective is to assess the dietary profile of children aged 6 to 15 in the rural region of Vakinankaratra, in order to estimate the extent to which their nutritional needs are met. This research centers on the following key question: what are the dietary profiles of school-aged children and the level of dietary diversity? The hypothesis suggests that their diet is primarily geared towards meeting energy requirements, at the expense of protein and micronutrient intake. To this end, a systemic approach based on the analysis of food consumption frequencies was employed, combining multiple correspondence analysis, discriminant factor analysis and benchmarking, in order to identify typological dietary profiles and their socio-economic determinants.

2. Materials and methods

2.1. Study area and sampling

The study was conducted in the Antsirabe II district (19°52’08’’ S and 47°08’54’’ E) in the Vakinankaratra region, which covers an area of 16,599 km^{2}and is situated in central Madagascar [6]. The region comprises 20 rural municipalities [6].

The study covered five communes and fifteen primary schools, based on a stratified sample taking into account geographical and administrative distribution, school locations, and the age group of the children. The five rural communes—three of which are in suburban areas and two in remote areas—were selected based on their location and the standard of living of the local population. Surveys were conducted in three schools per commune (Table 1).

Table 1 List of municipalities and schools involved

Municipality	**Children surveyed**		**School**	**Children surveyed**	
	Total	Percentage		Total	Percentage
Ambohibary	64	24	EPP Amboniatsimo	22	8
			EPP Antanetilava	20	7
			EPP Anosy	22	8
Antsoatany	44	16	EPP Antsampanimahazo	22	8
			EPP Antsoatany	22	8
Ibity	66	25	EPP (Ecole Communautaire) Ibity	22	8
			EPP Firavahana	23	9
			EPP Mananjara	21	8
Belazao	62	23	EPP Belazao	23	9
			EPP Amboniavaratra	17	6
			EPP Ambohinapetraka	22	8
Antanimandry	33	12	EPP Ambohidrano	17	6
			EPP Antanimandry	16	6
TOTAL	269	100		269	100

The list of pupils from Year 1 to Year 6 served as the basis for the survey. Ten children aged 6 to 9 and 10 children aged 10 to 15 were selected at random from each school. On average, 20 children per school were surveyed. As two schools withdrew, the total number of children planned was 250. Taking into account a refusal rate of 5%, 269 children aged 6 to 15 were included.

2.2. Food consumption survey via interviews

An assessment of dietary history and the frequency of food consumption was carried out among 269 children aged 6 to 15 years [4]. The survey was conducted between 15 January and 16 February 2024. Photographs of foods were used to help the children identify them [7]. The questionnaire covered the child's socio-demographic characteristics, the household's socio-economic conditions, and the child's food consumption over a long period (the lean 1 season), specifically from October to February. The survey took 10 to 15 minutes per child.

2.3. Data preparation

Data entry and analysis were carried out using EXCEL and XLSTAT software. Each row corresponds to a household and a school-age child (or a 'reference' child from the household). The database was checked to remove odd characters (spaces, "-", etc.). Quantitative variables such as weight, height, BMI and household size were recoded as qualitative variables. N/A entries and missing values were replaced with W.

2.4. Factor analysis

2.4.1. ACM: a systemic view of households

The active variables are all those describing the household and the child's context. The additional variables are the food consumption variables (children's profiles). These were used for the dietary profiling of the axes and, later, the classes. The characterization of dietary profiles was carried out using a systemic analysis, which involved differentiating them by utilizing variables formed from the child's individual factors, household-related factors, and food consumption frequencies in interaction. Multiple correspondence analysis (MCA) aims to reveal relevant relationships between variables. The MCA plot determines the classes of individuals according to their positions relative to the factor axis. Depending on the angles formed by the vectors, those greater than 90° are in opposition, and those less than 90° are in concordance.

2.4.2. DFA and Benchmarking

A discriminant factor analysis (DFA) based on the classes obtained by MCA was carried out to determine the differentiating variables and the influential and dominant variables. Variables with a p-value >0.2 were eliminated as they are considered non-significant. The results of the MCA enabled the grouping of variables and individuals with common characteristics. Subsequently, the class obtained by ACM was used for the DFA to determine the relationships between the variables and to establish the p-value. After eliminating these variables, the ranking function obtained from the DFA was used to determine the value of each remaining variable. The following formula was applied to construct stochastic matrices:

- Convert negative variables into positive variables:

Value of a variable for a class − minimum value for the classes

- Normalize all positive variables: $\frac{\text{Value of the variable for a class}}{\text{Total value of the variables per row}}$

These stochastic matrices, verified by ensuring that the sum of each row equals 1, were used to plot the scatter plots corresponding to the benchmarking by class. The maximum value for each variable corresponds to the reference value or benchmark.

2.5. Calculation of the Dietary Diversity Score (DDS)

The dietary diversity score per child was calculated as follows: the first step involves grouping foods into food groups. Eight food groups were established based on their nutritional value, namely cereals, vegetables, pulses, fruit, animal products, dairy products, fats, and sugars/snacks/sweetened drinks.

Foods consumed every day (T) and often (S) are coded as '1'; those not consumed regularly (J), (R), (X) are coded as '0'. For each group, '1' is assigned if at least one food in the group is consumed regularly (S or T), otherwise 0. This yields

the score for the cereals group (G_CER), vegetables (G_LEG), pulses (G_LEGUMI), fruit (G_FRU), animal-sourced foods (G_ANIM), dairy products (G_LAIT), fats (G_GRA), and sweets (G_SUCR). The dietary diversity score is then the sum of the scores for the 8 groups.

Once the groups have been coded as 0/1, the child DDS corresponds to the sum of the groups consumed regularly; the child DDS therefore ranges from 0 to 8.

DDS (child) = G_CER + G_LEG + G_LEGUMI + G_FRU + G_ANIM + G_LAIT + G_GRA + G_SUCR

Next, the mean, median, minimum and maximum values of the DDS are calculated. The categories are classified as follows:

- Low DDS: 2–4
- Moderate DDS: 5–6
- High DDS: ≥ 6

3. Results

3.1. Sociodemographic characteristics of the children

The average age of the children surveyed is 9.3 years. They have an average weight of 22.4 kg and an average height of 121.8 cm. Nearly 90% of the children were fully vaccinated. The rate of chronic malnutrition was relatively high, with a prevalence of 43%, comprising 35% mild, 7% moderate and 1% severe cases (Table 2).

Table 2 Sociodemographic characteristics of the children

Characteristics	**Mean ± Standard deviation**	
Average age	9.3 ± 2.17	
Mean weight	22.4 ± 0.31	
Average height	121.8 ± 0.68	
Average BMI	14.9 ± 0.07	
Gender	Sample size	Percentage
G	137	50.9
F	132	49.1
Vaccination		
Non	23	8.5
Oui	246	91.4
Age group		
6 – 9 ans	123	45.7
10 – 14 ans	146	54.2
Child status		
Ill	84	31.2
In good health	185	67.8
Nutritional status		
Normal	153	56.8
Mild Malnutrition	93	34.5
Moderate Malnutrition	20	7.4

Severe Malnutrition	2	0.7
Overweight	1	0.3

3.2. Classes obtained by ACM

This research highlights the divergence and convergence in the dietary intake of school-agechildren in the Vakinankaratra region, emphasising the inequality in the fulfilment of their nutritional needs. It has highlighted the existence of four classes (C1, C2, C3 and C4); classes C1 and C4, forming an angle of less than 90°, appear to converge and are grouped into a single entity under class C1. This results in the grouping into three classes: C1, C2 and C3.

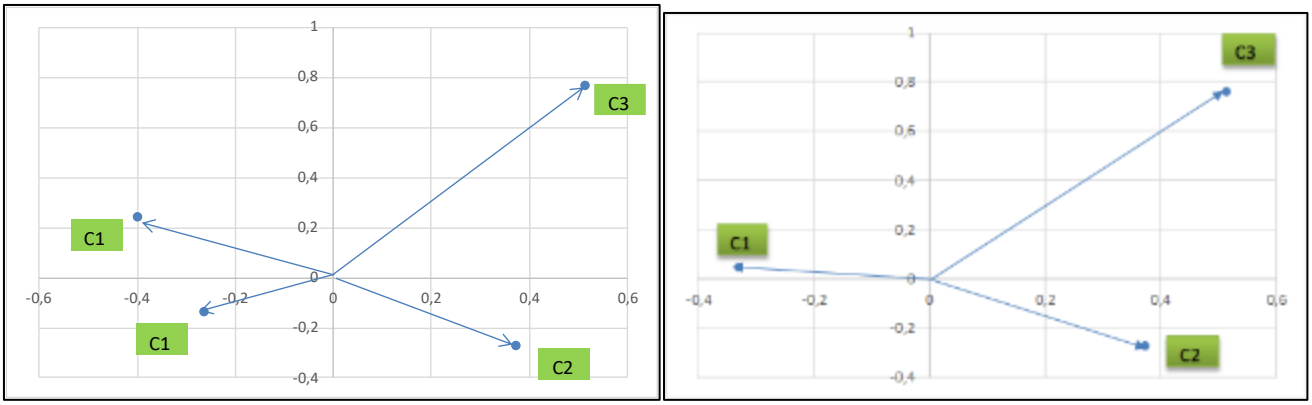


Figure 1 Convergence and divergence of classes according to ACM

The three classes obtained are distributed according to their respective characteristics:

- Class 1: Poorest households, children's diet lacking in variety (25.3%)
- Class 2: Intermediate profile, average households with moderate diversity (58.4%)
- Class 3: Most affluent households, most diverse children's diets (16.4%)

3.3. Household typology and dietary profiles

The typological analysis highlights three clearly distinct socio-economic profiles, whose

characteristics reflect both the structural conditions of vulnerability. Class 1 (68 households or 25.3%) comprises the most vulnerable households, located mainly in remote areas and poorly integrated into markets. Their diet remains dominated by staple foods and is characterised by extremely limited diversity, particularly in terms of animal proteins, fruits and dairy products (Figure 2). Class 2 (157 individuals, or 58.4%), an intermediate group, has more regular access to animal proteins but remains largely deficient in protective food groups, revealing a transitional profile in terms of food security (Figure 3). In contrast, Class 3 (44 individuals, or 16.4%) has more favorable living conditions and greater economic stability (Figure 4). This class exhibits the highest levels of dietary diversity and quality.

Figures 2, 3 and 4 illustrate the dietary profiles of the three classes based on the results of the benchmarking exercise. These results highlight the dietary variables that contribute most significantly to differentiating the three classes identified in the typology. Unlike approaches focused on high consumption, the benchmarking reveals that it is essentially the patterns of non-consumption ("never" or "very rarely") of certain foods that drive the differentiation between dietary groups, which are particularly pronounced and discriminatory, yet exhibit greater dietary diversity than Class 1.

Class 1 is strongly associated with "never" consumption for several foods — QZEB_J (beef), QCRT-J (carrot), QLTU-J (lettuce), QPVR-J (pepper) and QSOJ-J (soya) — which appear to be the major determinants of the profile. These foods are almost systematically absent from the diet of this class, indicating a structurally restricted diet characterised by low diversity. Thus, repeated deprivation of this same group of foods is responsible for the statistical distinctiveness of this class (Figure 2).

None of the measures examined reaches the maximum value for Class 2. The standardised coefficients consistently indicate an intermediate position, reflecting a profile that is neither severely deficient like Class 1, nor focused on the

absences observed in Class 3. This class appears to correspond to a less polarized diet, possibly more varied or at least characterised by extremes of non-consumption (Figure 3).

Class 3 is distinguished by 'never' or 'very rarely' responses for another set of foods - notably animal proteins (QOEU-X), cucumber (QCON-J), bread (QPAI-J), pumpkin (QPX-J) and voandjou (QVDJ-X). This class therefore does not share the same deficiencies as Class 1, but rather presents an alternative deficit profile, relating to a different range of foods. Several of these variables display the highest coefficients in the benchmark, making Class 3 a group characterised by particularly marked and discriminatory food absences, yet with greater dietary diversity than Class 1 (Figure 4).

3.3.1. Class 1 – Poorest households, children's diets lacking in variety

- Socio-economic characteristics

Class 1 represents the most disadvantaged socio-economic class, consisting mainly of 'poor' (P) households (57%), 'middle-income' (M) households (35%), and 'rich' (R) households (7%). The geographical distribution of households in this class shows that they are concentrated in the municipality of Belazao and particularly in Ibity, but very few are found in the municipality of Ambohibary. They are less well-equipped than other classes, notably with a very low proportion of households possessing certain comfort goods (BPB, BPZ). Housing conditions are rather basic: the flooring and building materials are fairly simple, and access to water and energy is broadly comparable to Class 3, but without any over of 'more favourable' arrangements. In summary, Class 1 comprises predominantly poor households, concentrated mainly in certain municipalities (Belazao and Ibity), with fewer amenities and modest living conditions.

- Dietary profile

Class 1 is strongly associated with the 'never' category for several foods — beef (QZEB_J), carrots (QCRT-J), lettuce (QLTU-J), peppers (QPVR-J) and soya (QSOJ-J) — which appear to be the major determinants of the profile. These foods are almost systematically absent from the diet of this class, indicating a structurally restricted diet characterised by low diversity. Thus, repeated deprivation regarding this same group of foods is responsible for the statistical distinctiveness of this class.

In terms of food groups consumed regularly (often or very often), Cereals/tubers are very common (≈ 91% of children) – this is the common foundation. Vegetables/legumes are almost universal, at 98%. As for animal products (meat/fish/eggs), only ~60% of children consume them, which is significantly fewer than in the other classes. Dairy products (milk, yoghurt, cheese, butter) are virtually absent: barely 4–5% of children consume them regularly. The same applies to fruit: only 48% of children eat at least one piece of fruit regularly, which is better than Class 2 but significantly lower than Class 3. Their diet is dominated mainly by sweet products and drinks (coffee, tea, biscuits, sweets, condensed milk, etc.). Around 59% of children consume at least one sugary product or a hot drink regularly (Figure 2)

- Dietary Diversity Score (DDS)

Their Dietary Diversity Score (DDS) is based on 5 food groups (cereals, vegetables/legumes, fruit, animal products, milk). The average DDS is 3 groups, with 27–28% of children having low diversity (≤ 2 groups) and 0% achieving 'high' diversity (5 groups).

In summary, children in Class 1 households have a diet centred on starchy foods and vegetables/pulses, with lower intakes of animal products and virtually no dairy products. Overall diversity is the lowest of the three classes, with a significant proportion of children experiencing insufficient dietary diversity (Figure 2)

3.3.2. Class 2 – Intermediate profile, average households with moderate diversity

- Socio-economic characteristics

Class 2 comprises households in the 'middle' (M) socio-economic category (CLECO), which predominates (~51%), 38% 'poor' (P), and 12% 'rich' (R). It is an intermediate class, neither the poorest (1) nor the most affluent (3). The geographical distribution is more balanced across the municipalities of Ambohibary, Belazao, Ibity, Antsoatany and Antanimandry. The level of household assets (BPC-cart, BPB-bicycle, BPZ-zebu) is higher than in Class 1, but generally lower than in Class 3. Housing conditions are in the middle range, neither the most precarious nor the most 'comfortable'. In summary: Class 2 comprises households of intermediate socio-economic status, relatively geographically diverse, with average levels of equipment and living conditions.

None of the categories studied achieves a maximum value for Class 2. The standardised coefficients consistently indicate an intermediate position, reflecting a profile that is neither severely deficient like Class 1, nor focused on the absences observed in Class 3. This class appears to correspond to a less polarised pattern, possibly more varied or at least characterised by extremes of non-consumption.

- Dietary profile

In terms of food groups consumed regularly (often or very often), the consumption of cereals and tubers is also almost universal (≈ 97%). The same applies to vegetables and pulses, which are very common (≈ 99%) for this class. Animal products such as dried fish (QPSS) are frequently consumed by 76% of children – higher than Class 1, but lower than Class 3. The consumption of dairy products is higher than in Class 1, at 27% of children, but significantly lower than in Class 3. As for fruit, around 43% of children consume fruit regularly – less than Class 1 and, in particular, less than Class 3. Sweets/drinks: 66% (intermediate level) (Figure 3)

- Dietary Diversity Score (DDS)

The dietary diversity score averages around 3.4 food groups (a value between Class 1 and 31 Class 3). The proportion of children by diversity score is 15% with low diversity, 75% with 32 moderate diversity, and 10% with high diversity.

In summary, children in Class 2 have a moderately diverse diet: better than Class 1 (more animal products and dairy), but less varied than that of children in Class 3, particularly in terms of fruit and dairy products.

3.3.3. Class 3 – Most affluent households, most diverse children's diet

- Socio-economic characteristics

Class 3 comprises the most affluent households, consisting of 27% of households classified (CLECO) as 'rich' (R) – the highest proportion – 41% as 'middle-income' (M) and 32% as 'poor' (P). Geographically (COM), they are heavily concentrated in the municipality of Ambohibary (~52%), followed by Belazao and Antsoatany. One might assume a more urban/suburban profile or better connectivity. In terms of facilities and assets, this is the class 10 best endowed with assets (BPC, BPB and BPZ: cart, bicycle, zebu, etc.) and they are significantly more often 'O' (present) than in the other two classes. Regarding housing conditions, this class has the highest proportion of households with a C-type floor (improved/concrete floors) compared to Class 1. Access to water and energy is at least equivalent, if not slightly more favourable. In summary, Class 3 comprises relatively well- off, better-equipped households, heavily concentrated in the municipality of Ambohibary, with the most favourable living conditions of the three classes.

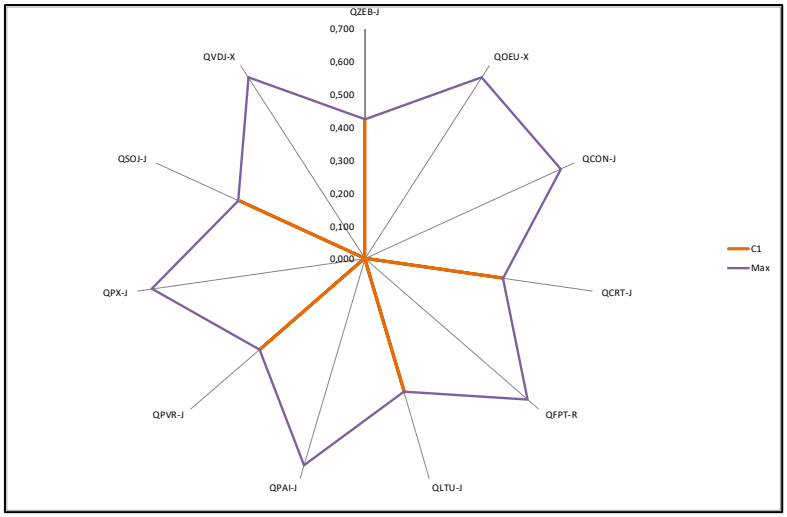
- Dietary profile

Class 3 is distinguished by 'never' or 'very rarely' responses for another set of foods — notably animal proteins (QOEU-X), cucumber (QCON-J), bread (QPAI-J), pumpkin (QPX-J) and voandjou (QVDJ-X). This class therefore does not share the same deficiencies as Class 1, but rather presents an alternative deficiency profile, relating to a different range of foods. Several of these variables have the highest coefficients in the benchmark, making Class 3 a group characterised by absences.

Regarding food groups, cereals and tubers, as in all other classes, constitute the most frequently consumed foods; practically all children (≈ 98%) consume them regularly. Almost 100% of children consume at least one vegetable or legume regularly. Consumption of foods of animal origin is the highest compared to the other classes; 93% of children consume them regularly, which is the highest figure. Dairy products are also significant, with 50% of children regularly consuming milk or dairy products (a stark contrast to Class 1). As for fruit, 66% of children eat at least one type of fruit often or very often (bananas, mangoes, oranges, etc.) – again, significantly higher than in other classes. Sweets and drinks are also important, 32 with 71% of children consuming at least one sweet or sugary drink regularly. (Figure 4)

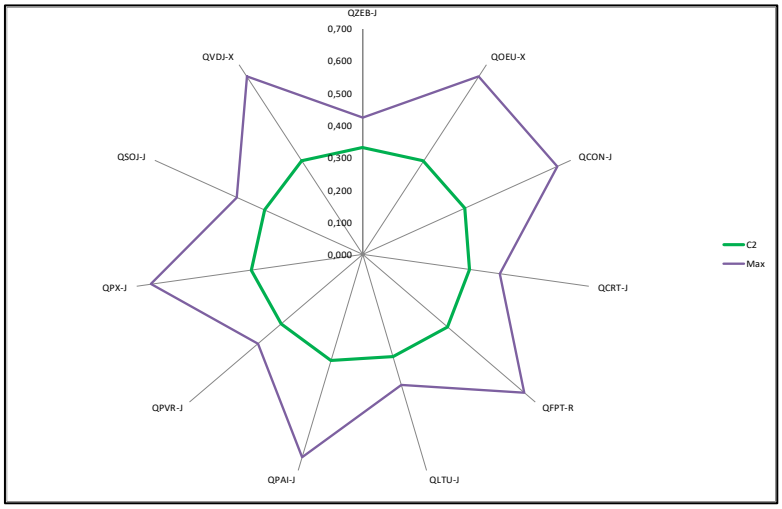
- Dietary Diversity Score (DDS)

The dietary diversity score is relatively high, with an average of 4.1 food groups (the highest); only 2% of children have low diversity (≤ 2 food groups) and around 34% of children achieve high diversity (5 food groups).



LEGENDS	
Variable	**English description**
QZEB_J	Beef consumption (never)
QOEU_X	Egg consumption (never)
QCON_J	Cucumber consumption (never)
QCRT_J	Carrot consumption (never)
QFPT_R	Sweet potato leaves consumption (rarely)
QLTU_J	Lettuce consumption (never)
QPAI_J	Bread consumption (never)
QPVR_J	Pepper consumption (never)
QPX_J	Pumpkin consumption (never)
QSOJ_J	Soybean consumption (never)
QVDJ_X	Groundnut consumption (very rarely)

Figure 2 Class 1 – Poorest households, children's diet lacking in variety



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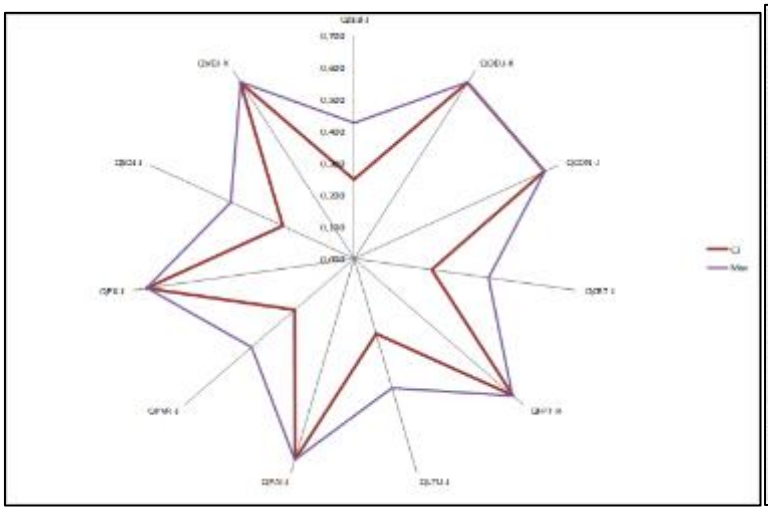
QFPT_R	Sweet potato leaves consumption (rarely)
QLTU_J	Lettuce consumption (never)
QPAI_J	Bread consumption (never)
QPVR_J	Pepper consumption (never)
QPX_J	Pumpkin consumption (never)
QSOJ_J	Soybean consumption (never)
QVDJ_X	Groundnut consumption (very rarely)

Figure 3 Class 2 – Intermediate profile, average households with moderate diversity



LEGENDS	
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QCON_J	Cucumber consumption (never)
QCRT_J	Carrot consumption (never)
QFPT_R	Sweet potato leaves consumption (rarely)
QLTU_J	Lettuce consumption (never)
QPAI_J	Bread consumption (never)
QPVR_J	Pepper consumption (never)
QPX_J	Pumpkin consumption (never)
QSOJ_J	Soybean consumption (never)
QVDJ_X	Groundnut consumption (very rarely)

Figure 4 Class 3 – Most privileged households, most diverse children's diet

In summary, children in Class 3 households benefit from a significantly more diverse diet with a high proportion of animal products, dairy products and fruit, in addition to the staple of starchy foods and vegetables. This is clearly the 'advantaged' class and the one best served nutritionally.

4. Discussion

4.1. Dietary profile of the three classes

The results highlight a clear differentiation in households' dietary patterns and living conditions. The three classes — representing 25% (Class 1), 59% (Class 2) and 16% (Class 3) respectively — illustrate distinct trajectories in terms of multidimensional vulnerability and food security [8][9][19].

4.1.1. Class 1: extreme vulnerability and a survival diet — manifestation of 'poverty traps'

Class 1 is characterised by structural poverty, limited access to markets and very low economic integration. Its diet — consisting mainly of cereals, with virtually no fruit or dairy products — corresponds to the profiles of survival diets observed in contexts where households are caught in "poverty traps" [12]. The results confirm that poor households adopt diets that are high in calories but low in nd micronutrients, due to the high cost of fresh produce [11][20]. This class combines economic, nutritional and geographical vulnerabilities, making it a priority for humanitarian interventions.

4.1.2. Class 2 : 'hidden hunger'

None of the modalities studied reaches a maximum value for Class 2. The standardised coefficients indicate an intermediate position, reflecting a profile that is neither severely deficient like Class 1 nor absent like Class 3. This majority class exhibits "hidden hunger": chronic micronutrient deficiency despite apparent food security [13][15][16]. Deficits in fruit and dairy products can be explained by low local availability of fresh produce, volatile seasonal prices, underdeveloped value chains, and poor connectivity to markets [17][18]

Caloric security does not guarantee nutritional security, as demonstrated in African food systems.

4.1.3. Class 3 : a high-performing profile

Class 3 has the best indicators, with standardised scores of 100/100 for cereals, animal proteins, fruit and dairy products, reflecting stable resources [10].

4.2. Nutritional inequalities driven by 'expensive' foods

Discriminant Factor Analysis shows that differentiation is based on expensive/perishable foods such as fruit (61.5% LD1; 69.5% LD2), dairy products (20.5%; 26.4%), and leafy vegetables (15.6%) [14][15][16]

This structure confirms the cost of the minimum diet and the economic barriers to micronutrients [14]. This structure is consistent with the literature on the cost of the minimum diet, economic barriers to accessing micronutrients [15], and the hierarchy of food access in contexts of poverty [16].

Thus, the differentiation between households is not determined by caloric intake, but by the financial and logistical capacity to acquire protective foods, a key point in understanding nutritional vulnerability in Madagascar.

The results of this study reveal a dietary structure deeply marked by inequalities in access to 26 protective foods, confirming the dynamics observed in contexts of chronic poverty and structural food insecurity. The three classes identified — ranging from the survival diet (Class 1) to the diversified diet (Class 3), via invisible nutritional vulnerability (Class 2) — illustrate the coexistence of divergent dietary trajectories within the same territory subject to severe climatic, economic and logistical constraints [22].

Across the board, these analyses show that dietary diversity—and not merely caloric intake constitutes the main axis of nutritional differentiation. This observation is consistent with the literature demonstrating that vulnerable households compensate for economic deficits with

diets based mainly on cereals, tubers and a few animal products, to the detriment of fruit, dairy products and leafy vegetables, which are generally more expensive, perishable and dependent on fragile supply chains [16,17].

Class 1 clearly illustrates the mechanisms of poverty traps described by Barrett and Carter (2006) [10]: limited resources, low dietary diversity, inability to invest in nutritious food, and 5 the intergenerational reproduction of vulnerability. In contrast, Class 3 highlights the pivotal 6 role of access to a diverse diet, consistent with analyses of the protective effect of cash or food transfers in sub-Saharan Africa [18, 23].

Class 2, which represents the majority, reflects an intermediate situation observed in many rural areas: partial stability, acceptable calorie security, but persistent micronutrient deficiencies — a typical form of hidden hunger [12,13,22].

The results also highlight a key mechanism of differentiation: it is the most expensive foods and those most sensitive to climatic disturbances that drive inequalities between households. Fruit, dairy products and animal proteins — identified as the discriminating variables in the AFD — are scarce nutritional commodities in isolated rural areas, confirming the decisive role of economic and geographical accessibility in shaping nutritional vulnerability.

Finally, this study provides important insights for planning interventions: it shows that aid programmes do not benefit all categories of households equally, and that only differentiated approaches — tailored to vulnerability categories — can mitigate structural inequalities. It also highlights the importance of integrating detailed analyses of food consumption into early warning systems and resilience strategies [21]

The identified groups illustrate divergent trajectories within a constrained environment. Dietary diversity is a greater determinant than calorie intake [7][18]. Interventions must target protective foods using approaches differentiated by profile [23][24].

5. Conclusion

The aim of this study is to establish the dietary profile of school-age children in rural areas in order to determine the extent to which their nutritional needs are met. It highlights three distinct dietary profile, revealing nutritional inequalities deeply rooted in local socio economic and climatic dynamics. Class 1 comprises the most vulnerable households, trapped in mechanisms of structural poverty and exhibiting a highly restrictive diet, consistent with the survival diets described in the literature. Class 2, although more stable, remains in a situation of hidden nutritional vulnerability, with persistent micronutrient deficiencies despite apparent caloric security. Finally, Class 3 illustrates that some better-off households manage to improve their diets, corroborating studies conducted in various African contexts. The hypothesis that dietary profiles primarily meet energy needs but are deficient in animal protein and micronutrients is thus confirmed. The results show that access to protective foods — fruit, dairy products, animal proteins — is the main determinant of nutritional inequalities, far more so than caloric intake. This finding is consistent with analyses of the cost of the minimum diet and the economic barriers to acquiring nutritious foods. Three key operational implications emerge: Class 1: critical priority — urgent interventions targeting protective foods, cash transfers and economic support; Class 2: intermediate priority — interventions aimed at dietary diversification and market access; and Class 3: consolidation — strengthening resilience and maintaining positive practices.

From a scientific perspective, this research demonstrates the relevance of combined approaches (ACM, AFD, benchmarking) for understanding nutritional vulnerability. Future directions include the integration of anthropometric indicators, the analysis of gender norms, and the consideration of seasonality and climate shocks. In summary, dietary diversity remains a central public health issue. This study highlights the urgency of promoting food environments that enable equitable access to healthy and protective food for all.

Compliance with ethical standards

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Disclosure of conflict of interest

We, authors of the present manuscript, declare that we have no conflict of interest concerning the present research.

Statement of informed consent

Participation was voluntary. The purpose of the study was explained to each participant before the interview, and informed consent was obtained before questionnaire administration.

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