

## Strategic model for sustaining coverage of the nutritional needs of school-aged children in rural Madagascar

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### Abstract

In Madagascar, the nutrition of school-age children is a strategic issue at the intersection of food security. In the Malagasy context, school feeding appears to be a major lever for social protection and resilience. However, ensuring adequate nutritional coverage in the long term does not depend solely on the existence of school canteens. In light of this issue, this research aims to propose a strategy to ensure the long-term coverage of their nutritional needs. Thus, the research question is: 'How can we develop, based on observed dietary profiles and key variables of the food system, a sustainable strategy to meet their nutritional needs?' The hypothesis posits that identifying dietary profiles and strategic food variables enables the development of a relevant, hierarchical intervention model. Multiple Correspondence Analysis, Discriminant Factor Analysis and a MICMAC-type structural analysis were used to classify the variables according to their influence and interdependence. The study is based on two datasets: an anthropometric dataset of 2,464 children and a dietary dataset of 269 child-households. The results indicate a high prevalence of underweight status at 41%, with a marked increase among 10–15-year-olds. The malnutrition observed is not solely due to a lack of calories, but primarily to poor dietary diversity and limited access to protective foods. Three types of variables were examined: driving variables, which structure the food system; intermediary variables, which determine nutritional quality; and dependent variables, which reflect the system's outcomes. The model proposes an integrated strategy based on access to protective foods, school feeding, nutrition education, support for local production, and a multisectoral approach linking agriculture, health, education and social protection.

**Keywords:** Nutrition; Malnutrition; Household Typology; School Age Children

### 1. Introduction

In Madagascar, the nutrition of school-age children is a strategic issue at the intersection of food security, education and human capital development. Food security rests on four interdependent dimensions — availability, access, utilization and stability — the fragility of which compromises the quality of children's diets and their learning abilities [1].

The 'school food and nutrition' approach highlights the need to integrate the school food environment, nutrition education and links with local food systems, in order to improve both nutritional outcomes and academic performance [2][3].

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In the Malagasy context, school feeding emerges as a key driver of social protection and resilience. The World Food Programme reports that in 2024, the school meals programme implemented in partnership with the Ministry of National Education covered 385,000 children in 1,245 state primary schools, including 653 schools supported under the home-grown school feeding scheme [4].

At the same time, UNICEF highlights the need for a specific nutrition programme for children and adolescents, including nutrition education in schools and communication tools to combat malnutrition [5]. Recent research shows that integrated school programmes provide an effective platform for supporting the learning, health and nutrition of children and adolescents [6].

However, ensuring the sustainability of adequate nutritional coverage does not depend solely on the existence of school canteens. It requires a detailed understanding of local dietary determinants, constraints on access to protective foods, household vulnerability profiles and the strategic variables shaping the food system. Field data show a high prevalence of underweight status based on BMI-for-age among children aged 5 to 15 years, reaching 41.4% in the total anthropometric sample, with a marked increase among 10–15-year-olds (54%) [7].

In light of this issue, the overall objective of this research is therefore to propose a strategic model for ensuring the long-term coverage of the nutritional needs of school-age children. The specific objective is to identify dietary variables, categorised into driving, intermediary and dependent variables; to develop a strategic nutritional model; and to

discuss the programmatic implications for school feeding policies, territorial resilience and local food systems. This raises the research question: how can a sustainable strategy for meeting the nutritional needs of school-age children in Madagascar be developed, based on the observed dietary profiles and key variables of the food system? The hypothesis posits that the identification of dietary profiles and strategic dietary variables enables the development of a prioritised and relevant nutritional intervention model.

## 2. Materials and methods

### 2.1. Study site

The study took place in the district of Antsirabe II (19°52'08" S and 47°08'54" E) in the Vakinankaratra region, which covers an area of 16,599 km<sup>2</sup> and is situated in central Madagascar. It comprises 20 rural municipalities. The study covered five rural municipalities and fifteen primary schools.

### 2.2. Sampling and data collection

Anthropometric measurements were taken from all pupils aged 5 to 15 years attending 14 schools, in accordance with the 2007 WHO recommendations (Table 1).

**Table 1** Number of children aged 5 to 15 measured

Municipality	Number of children measured	
	Total	Percentage
Ambohibary	493	20
Ibity	707	29
Antsoatany	415	17
Belazao	559	23
Antanimandry	290	12
TOTAL	2 464	100

Data on the socio-economic situation of households and the dietary intake of children aged 5 to 15 were collected from 269 children, with an average of 20 per school (Table 2).

**Table 2** Number of children surveyed by commune and by institution

Local authority	School	Number of children surveyed	Percentage
Ambohibary	EPP Amboniatsimo	22	8
	EPP Antanetilava	20	7
	EPP Anosy	22	8
Antsoatany	EPP Antsampanimahazo	22	8
	EPP Antsoatany	22	8
Ibity	EC Ibity	22	8
	EPP Firavahana	23	9
	EPP Mananjara	21	8
Belazao	EPP Belazao	23	9
	EPP Amboniavaratra	17	6
	EPP Ambohinapetraka	22	8
Antanimandry	EPP Ambohidrano	17	6
	EPP Antanimandry	16	6
TOTAL		269	100

### 2.3. Study design and analytical approach

This research follows an analytical and prospective approach based on the combined use of anthropometric data, dietary intake data and structural analysis tools [8]. It constitutes a strategic modelling exercise aimed at identifying the priority levers for improving the nutrition of school-age children, rather than an experimental impact assessment of school canteens.

### 2.4. Conceptual references

The analytical framework draws on three complementary approaches:

- The four pillars of food security approach, according to which availability, access, 10 utilization and stability form the basis for the analysis of food systems [1].
- The human capital approach, according to which nutrition and education constitute complementary investments in future productivity [9]. The World Bank Group notes that in Madagascar, the human capital deficit remains strongly linked to malnutrition and poor educational quality.
- The school food and nutrition / home-grown school feeding approach, which links the demand for nutritious school meals to local production and regional value chains [2][3][4].

### 2.5. Variables and Indicators

Nutritional indicators are interpreted in accordance with WHO guidelines for 5–19-year-olds [10]. BMI-for-age is used to classify underweight, overweight and obesity, whilst stunting is assessed using height-for-age.

For dietary analysis, consumption frequencies were grouped as follows: Always consumed (A), Often consumed (O), Never consumed (N), Very rarely consumed (V), Rarely consumed (R).

The Dietary Diversity Score (DDS) was calculated using eight food groups: cereals/tubers, vegetables, pulses, fruit, animal products, dairy products, fats, and sugars/sweetened drinks. The categories 'often' and 'every day' were coded as 1, the others as 0, and then aggregated into a DDS ranging from 0 to 8.

### 2.6. Data source

The analysis is based on two datasets:

- - An anthropometric dataset of 2,464 children aged 5 to 15, used to describe nutritional status based on BMI-for-age (Anthrop2def.xls);
- - A dataset of 269 children/households used for the analysis of dietary practices, the typology of profiles and the identification of discriminating variables. (FreqAli2\_Def.xls)

The data used are drawn from the FreqAli2\_Def database, which contains information on the socio-demographic characteristics of households, the dietary habits of children aged 5 to 15, and anthropometric indicators of nutrition.

Dietary variables are coded according to the frequency of consumption of several food groups (cereals, vegetables, pulses, animal products, etc.). Within the strategic model, the analysis focuses on variables indicating low dietary intake, in particular:

- Never consumed 1
- Consumed rarely 2

These categories are used as indicators of dietary exclusion that may impair the diversity and nutritional quality of diets.

## 2.7. Analysis steps

The analysis was conducted in four sequential stages, combining multivariate statistics and structural modelling to validate the hypothesis. All operations were carried out using Excel, with defined statistical thresholds ( $p > 0.2$ ;  $|\rho| > 0.119$  calculated as the significance threshold for  $n=269$ ,  $\alpha=0.05$ ).

### 2.7.1. Household dietary typology

The aim of this stage is to identify homogeneous groups of households sharing similar food consumption profiles. Multiple Correspondence Analysis (MCA) followed by Discriminant Factor Analysis (DFA) were applied to food consumption frequencies (categories: never/rarely/often/always) and socio-economic variables. The analytical procedure comprises:

- Standardization of food consumption frequency variables
- Extraction of the principal axes of inertia using MCA
- Varimax rotation to improve the interpretability of the axes
- Classification of individuals using DFA with class assignment based on posterior probabilities, and
- Testing the significance of differences between classes (chi-square test)

### 2.7.2. Ranking of Variables

This step involves establishing a hierarchy of dietary variables according to their structural importance within the system. This is the method for analysing the correlation matrix derived from AFD (Pearson's correlation coefficient  $\rho$ ). The procedure comprises several steps involving the elimination of non-significant variables. Variables with a p-value greater than 0.2 (type I error risk  $\alpha$ ) are classified as non-significant and eliminated; these are removed from the lower diagonal section, and a significance threshold of 0.119 is applied. Only variables whose absolute values exceed the significance threshold for inter-variable correlations are retained. Next, variables with a  $|X_i| > |\rho|$  value of 'X' are replaced by 'X' for counting purposes. The number of occurrences of 'X' per row represents the number of significant outgoing connections for each variable. The minimum number of occurrences per row of 'X' forms the starting point for the ranking. The variables are transferred to a 'ranking' sheet and then deleted from their original sheet to allow processing to continue until all variables have been ranked. The sequence in which variables are eliminated determines their rank in the order in reverse: the last variables to be eliminated are considered to have priority in the final ranking.

### 2.7.3. Strategic Rectangle

The objective is to identify the dominant and influential variables, and consequently to classify the variables into drivers, intermediaries, dependents and autonomous elements of the food system according to their capacity for influence and their level of dependence. The method used is structural analysis inspired by Godet's (2007) MICMAC method (Matrix of Cross-Impact Multiplication Applied to a Ranking), adapted to the correlation matrix.

For each variable, the following indices were calculated:

$$Y = L \times P.$$

$X = L / P$ , where L is the sum of the absolute values in the rows and P is the sum of the absolute values in the columns.

Variables with  $X > 1$  were considered influential; among these, the highest values of  $Y$  were used to identify the dominant variables. This approach, inspired by MICMAC-type structural analysis methods, makes it possible to distinguish between driving, relay, dependent and autonomous variables.

The classification of variables is carried out as follows:

- Sort in descending order by  $X$ : variables with  $X > 1$  are considered 24 influential variables (marked in yellow) [8][11] 25
- Among the influential variables, sorted in descending order by  $Y$ : variables 26 with the highest  $Y$  values (up to a significant standard deviation) are 27 identified as dominant and driving variables (marked in green)

Each variable is positioned in the  $(X, Y)$  plane, defining four quadrants:

- **Q1 – Driving variables** : strong influence ( $X > 1$ ) , moderate dependence
- **Q2 – Relay variables** : strong influence ( $X > 1$ ) and strong dependence (high  $Y$ )
- **Q3 – Dependent variables** : low influence ( $X < 2$ ), high dependence (high  $Y$ )
- **Q4 – Autonomous variables** : low influence and low dependence

Selection of strategic variables : The variables used in the construction of the model were selected (Table 3)

#### 2.7.4. Construction of the Strategic Nutritional Model

Based on the position of the variables within the strategic rectangle, a simplified causal model was developed to represent the dynamics of the food system. The model comprises three hierarchical levels:

Determinant Variables (Strategic Levers) - Drivers

These are the variables capable of driving changes across the entire food system. They are 15 characterised by a strong influence ( $X > 1$ ) and low dependence (driving variables).

Relay Variables (System Pivots) - Relay

These are the variables that structure the diversity and nutritional quality of the diet. They exhibit both a strong influence ( $X > 1$ ) and a high degree of dependence (high  $Y$ ), thereby playing a central role in transmitting influences between components of the system. These variables constitute the nutritional pivots of the system as they determine the overall nutritional quality of diets.

Dependent Variables (Outcome Indicators)

These are the variables reflecting nutritional outcomes or changes in food access. They are characterised by low influence ( $X < 1$ ) and high dependence (high  $Y$ ).

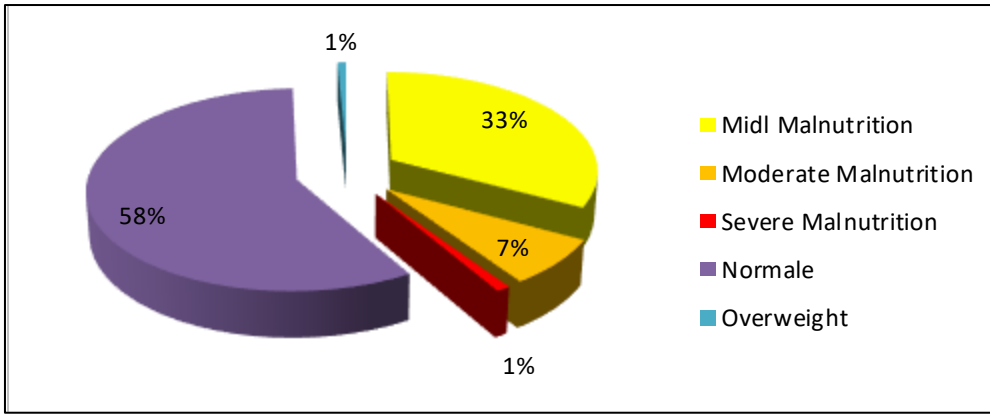
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## 3. Results

### 3.1. Nutritional Structure

The results show that the nutritional vulnerability observed stems not only from an overall energy deficit, but above all from a limited capacity to diversify towards protective foods.

In the anthropometric sample of 2,464 children, underweight status according to BMI-for-age reached 41%, comprising 33% mild cases, 7% moderate cases and 1% severe cases. Conversely, 57.8% of children have a normal nutritional status and overweight remains marginal (0.7%) [7]. (Figure 1)

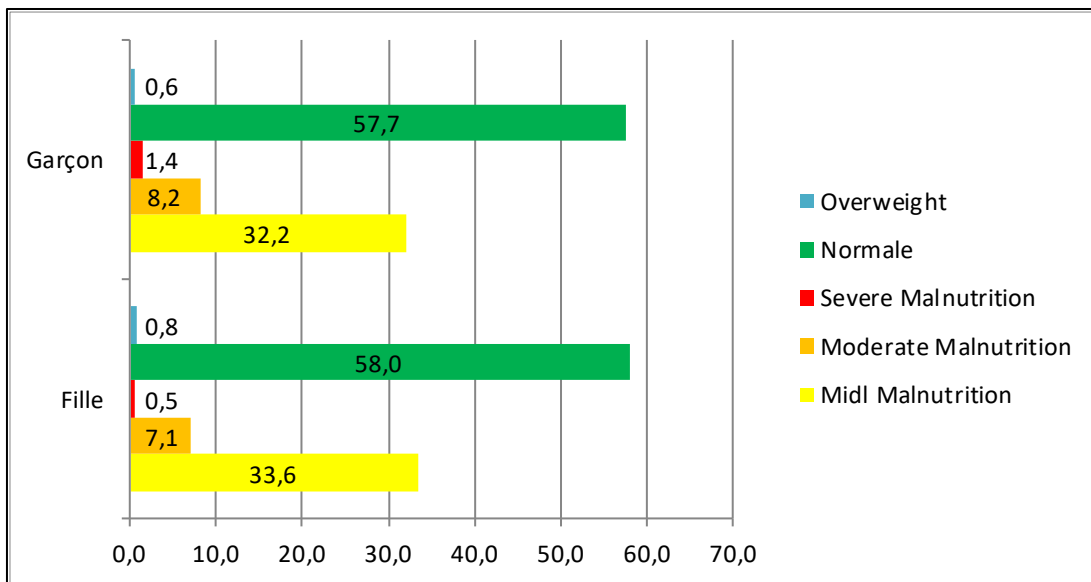


**Figure 1** Prevalence of underweight children aged 5 to 15 years (BMI-for-age)

**3.1.1. Breakdown by sex and age**

The prevalence of underweight status stands at 41% among girls, compared with 42% among boys ; the severe form is more common among boys (1%) than among girls (0.5%). This relative similarity suggests that nutritional vulnerability is largely shared.

The age gradient is very clear. Among 5–9-year-olds, the prevalence is 34% ; it rises to 54% among 10–15-year-olds. Moderate and severe forms increase sharply with age, rising from 4.7% among the youngest to 15.3% among the oldest. This result indicates an accumulation of nutritional deficits over the course of schooling [7] (Figure 2)



**Figure 2** Prevalence of underweight status by gender

**3.1.2. Regional disparities**

Based on municipal data, the prevalence of underweight is estimated at 52.8% in Ibity, 43.4% in Antanimandry, 37.9% in Belazao, 34.5% in Ambohibary and 33.7% in Antsoatany. Moderate and severe forms are particularly concentrated in Ibity (12.9%) and Antanimandry (11.0%). This spatial distribution indicates that nutritional vulnerability is not uniform and is likely exacerbated by regional constraints (Table 3)

**Table 3** Prevalence of underweight status by commune

Municipality	Number of children measured	Total malnutrition		Including moderate + severe	
		Total	Percentage	Total	Percentage
Ibity	707	373	52.8	91	12.9
Antanimandry	290	126	43.4	32	11.0
Belazao	559	212	37.9	41	7.3
Ambohibary	493	170	34.5	28	5.7
Antsoatany	415	140	33.7	20	4.8
TOTAL	2464	1021	41.4	212	8.6

### 3.2. Dietary typology and differentiation of profiles

Dietary analyses were carried out on 269 usable observations. The typology derived from 2 MCA and DFA highlights three distinct dietary profiles [7]:

- Class 1 : poorest households, poorly diversified diet
- Class 2 : intermediate profile, with partial calorie security but persistent deficits in protective foods
- Class 3 : best-off households, most diverse diet

The AFD shows that the differentiation between classes is mainly driven by fruit (61.5% of the variance on the first discriminant axis), followed by dairy products (20.5%) and certain leafy vegetables (15.6%). Conversely, staple foods show little discrimination between classes (cereals: ~2.1%).

In conclusion, the dietary divide observed relates less to minimum energy intake than to access to protective foods [7].

The average dietary diversity score (DDS) stands at around 3.4 groups out of 8, with 15% of children having low diversity, 75% having moderate diversity and 10% having high diversity. This pattern reflects a generally undiversified diet, dominated by a few major food groups.

### 3.3. Strategic model

#### 3.3.1. Identification of strategic variables

The structural analysis, carried out using the Influence–Dependence matrix, identified the most decisive dietary variables [8][11]. These results show that the most significant dietary omissions relate to three major nutritional groups [7][8], namely vegetables rich in micronutrients such as carrots, pumpkin, lettuce, peppers, cucumbers and sweet potato leaves; legumes and accessible plant-based protein sources (soya, voandjou); and finally animal protein sources (eggs, meat). (Table 4) The food system studied appears to be organised around a core of recurring deprivations that directly affect the nutritional 1 quality of the diet.

**Table 4** Influential and dominant variables

	Variables	Description of the variable	X=L/P	Y=L*P
<b>Influential and dominant variables</b>	QPAI-J	Pain (Jamais)	6,1	38,0
	QCRT-J	Carotte (Jamais)	3,3	48,8
	QLTU-J	Laitue (Jamais)	2,0	41,3
	QOEU-X	Œuf (Très rare)	1,8	30,8
	QPVR-J	Poivron (Jamais)	1,8	35,2
	QZEB-J	Viande de zébu (Jamais)	1,5	59,1
	QFPT-R	Feuille de patate (Rare)	1,5	42,8
	QSOJ-J	Soja (Jamais)	1,1	55,6
	QCON-J	Concombre (Jamais)	1,1	75,4
	QPX-J	Potiron (Jamais)	1,0	28,8
	QVDJ-X	Voandjou (Très rare)	1,0	44,9
<b>Influential variables</b>	QCON-X	Concombre (Très rare)	1,5	28,4
	QCRS-R	Cresson (Rare)	1,2	27,8
	QTOM-J	Tomate (Jamais)	1,6	27,0
	QCHO-J	Choux (Jamais)	3,5	26,8
	QFOC-R	Feuille de manioc (Rare)	1,5	26,6
	QOIG-T	Oignon (Tous les jours)	4,0	26,1
	QPX-R	Potiron (Rare)	1,3	25,0
	QCON-R	Concombre (Rare)	1,1	24,3
	QMAIF-J	Mais frais (Jamais)	3,9	23,6

### 3.3.2. Driving, Relaying and Dependent Variables

The strategic matrix highlights dominant and influential variables across three levels of structure [8][11]: driving variables, the deprivation of which can lead to the collapse of the entire system. These variables, such as QPAI\_J (Bread never consumed), which represent energy intake and have high X and Y values, influence the entire system. Relay variables, such as the vegetable and legume groups (Carrot (QCRT-J, Y=48.8), Soya (QSOJ-J, Y=55.6), Sweet potato leaves (QFPT-R, Y=42.8), Lettuce (QLTU-J, Y=41.3), which determine nutritional density, act as the linchpin of the system. Dependent variables such as animal products (eggs (QOEU-X, Y=30.8), zebu meat (QZEB-J, Y=59.1)) act as the system's outputs, and their consumption depends on the overall 14 functioning of the system (Table 5)

**Table 5** Classification of food variables according to the strategic rectangle

Type of Variable	of	Definition	Examples
Level Driving	1:	Most fundamental deprivations; influence the entire system	QPAI-J (never eaten bread); lack of accessible staple foods; but replaced by rice and sweet potato
Level Relays	2:	Foods that determine micronutrient density; pivotal links between food access and nutritional quality	Carrot (QCRT-J, Y=48.8), Soya (QSOJ-J, Y=55.6), Sweet potato leaves (QFPT-R, Y=42.8), Lettuce (QLTU-J, Y=41.3)
Level Dependent	3:	System outcomes; consumption depends on overall functioning	Animal products, eggs (QOEU-X, Y=30.8), zebu meat (QZEB-J, Y=59.1)

### 3.3.3. Design of the strategic nutritional model

Based on the empirical results, an integrated strategic nutrition model was designed. Its construction is based on four complementary pillars [5][2][4]:

- UNICEF's conceptual framework on the immediate, underlying and structural determinants of nutrition
- The FAO approach to school food and nutrition, which links school meals, a healthy food environment and local production

- The WFP's approach, which views school meals as an investment in human capital and a lever for territorial development
- The empirical results of the study derived from ACM, AFD, sequencing and the Influence–Dependence rectangle

The model is organised into four hierarchical levels [7][8] :

#### Structural determinants

Structural determinants consist of household poverty, market access conditions, regional food availability, agricultural seasonality, logistical constraints and the environmental health context. These factors constitute the underlying causes that determine actual access to adequate food.

#### 3.3.4. Driving variables of the food system

These are the variables that reflect structural deprivations and alter the overall 2 composition of the diet, such as bread, rice and pasta (QPAI\_L, QRIZ\_T, QPAT\_S). They 3 act as strategic levers, the improvement of which triggers a chain reaction.

#### 3.3.5. Nutritional quality proxy variables

Micronutrient-rich vegetables, pulses and accessible proteins (Carrot (QCRT-J, Y=48.8), Soya (QSOJ-J, Y=55.6), Sweet potato leaves (QFPT-R, Y=42.8), Lettuce (QLTU-J, Y=41.3), eggs (QOEU-X, Y=30.8), zebu meat (QZEB-J, Y=59.1). These foods underpin the diversity and nutritional density of the diet, acting as essential cornerstones.

#### 3.3.6. Nutritional results

Insufficient dietary diversity, poor quality of intake and high prevalence of underweight (BMI-for-age). Nutritional status, as measured by age-adjusted BMI, serves as a composite outcome variable for the system. In addition to this core chain, there are moderating factors:

- School meals and canteens
- Nutrition education
- School health programmes
- Support for local production and school vegetable gardens [2][4][5]

This model highlights that improving children's nutritional status does not depend on a single intervention, but on a combination of actions acting simultaneously on food access, dietary diversification, the educational environment and territorial resilience.

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## 4. Discussion

### 4.1. Nutritional Outcome: Beyond Generalised Underweight

The first major finding of this research is the high level of nutritional vulnerability observed among school-age children. A prevalence of 41% of underweight children based on BMI-for-age indicates that nutritional deficiencies are not limited to early childhood but persist throughout school age [7]. The marked worsenin among 10–15-year-olds confirms that middle childhood and early adolescence are critical periods during which 1 nutritional requirements increase, even as diets remain insufficiently varied.

This finding is in line with recent UNICEF guidelines in Madagascar, which emphasise the need to no longer focus nutritional efforts solely on children under five, but also on older children and adolescents [5][6].

### 4.2. Nutritional vulnerability beyond calorie deficit

The second major finding is that nutritional vulnerability is not limited to an overall energy deficit. The AFD clearly indicates that the most discriminating foods are not staple foods, but fruit, dairy products and animal proteins [7]. In other words, what distinguishes dietary profiles is not primarily calorie intake, but households' ability to access protective foods, which are more expensive, more perishable or more dependent on markets [12][13] [14](Table 4)

These findings are consistent with research showing that, in contexts of poverty, minimum calorie intake can coexist with marked deficiencies in micronutrients and high- quality protein [12] [14].

#### 4.3. Major implications for nutrition policy

A strategy focused solely on energy intake or the distribution of staple foods would be insufficient to sustainably address the observed vulnerability. The study's findings instead suggest prioritising foods that enhance the nutritional density of the diet: vegetables rich in provitamin A, pulses, eggs, meat, dairy products and fruit [5][10].

#### 4.4. Scientific Value of the Proposed Model

The scientific value of the strategic model developed lies in its ability to link descriptive statistical results to a systemic and operational interpretation [8][11]. The ACM and AFD enable the identification of dietary profiles and fault lines; the sequencing prioritises the variables; the structural analysis distinguishes between levers for action and simple outcome indicators.

This model also has the advantage of being compatible with major international frameworks [2][4][5]:

- The UNICEF framework enables results to be placed within a causal chain 1 ranging from social resources and norms to diets and nutritional status. 2
- The FAO framework on school food and nutrition allows schools to be integrated 3 as a space for intervention on dietary habits, the food environment and links with 4 local production. 5
- The WFP approach allows school meals to be viewed not merely as aid, but as a 6 simultaneous investment in nutrition, education, social protection and local 7 development.

#### 4.5. Implications for the sustainability strategy

From an operational perspective, the findings support a sustainability strategy based on five complementary pillars [2][4][7]:

- **Ensuring regular access to protective foods.** The results show that it is the repeated lack of accessible vegetables, pulses and proteins that most strongly determines nutritional vulnerability (Table 2).
- **Localising the nutritional response.** Differences between municipalities show that a one-size-fits-all approach would be ineffective. Municipalities such as Ibity and Antanimandry must be considered priorities (Table 1).
- **Design school feeding as an instrument of transformation.** School feeding must become a vehicle for transforming the local food system, by combining food education, a healthy school environment and links with local production [2][4].
- **Adopt a multi-sectoral approach.** Dietary quality depends on income, local supply, seasonality, the health environment and nutritional information. Coordination between agriculture, education, health, nutrition, social protection and local authorities is essential [4][9].
- **Integrate food and climate resilience.** In the rural areas of the Highlands, dependence on fragile production and market systems exposes households to repeated shocks. A sustainable strategy must strengthen the capacity of households and schools to maintain a diverse diet during times of stress.

#### 4.6. Limitations and scope of the research

This discussion must, however, be read in the light of three limitations. Firstly, the study is based on cross-sectional data, which does not allow for the establishment of a strict causal link between each dietary practice and nutritional status. Secondly, the frequency of consumption provides information on habits, but not directly on the quantities ingested. Finally, age-adjusted BMI provides information on leanness rather than stunting; it therefore captures part, but not all, of nutritional vulnerability.

Despite these limitations, the convergence between dietary typology, structural analysis and anthropometric results lends strong consistency to the proposed model.

## 5. Conclusion

The results of this research show that ensuring the long-term fulfilment of the nutritional needs of school-age children in Madagascar cannot be achieved through a strictly caloric approach, nor through an exclusively sectoral approach. It requires an integrated strategy, based on:

- The identification of the driving and intermediary variables of the food system;
- The targeting of protective foods (micronutrients and high-quality proteins);
- Differentiating vulnerability profiles by region and social group;
- The coordination of school feeding, local production, nutrition education and territorial resilience.

The strategic model developed in this research provides a credible analytical and operational framework to guide public policies and school nutrition program in the Malagasy Highlands, in line with the priorities of UNICEF, FAO and WFP for the period 2024–2030.

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## Compliance with ethical standards

### *Acknowledgments*

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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 ethical approval*

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

### *Statement of informed consent*

Informed consent was obtained from all individual participants included in the study.

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