



A typology of food consumption patterns in ASEAN: A cluster analysis of convergence and divergence (2010-2022)

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Received Date: December 6, 2025

Revised Date: January 25, 2026

Accepted Date: February 26, 2026

ABSTRACT

Background: The Association of Southeast Asian Nations (ASEAN) is a global epicenter of the nutrition transition, where rapid economic growth, urbanization, and globalization are profoundly reshaping food consumption patterns. This study aims to quantitatively map the evolving typology of dietary patterns across ASEAN and determine whether homogenization, divergence, or a multi-polar clustering best characterizes the region's food consumption evolution from 2010 to 2022. **Methods:** This research analyzes detailed FAO Food Balance Sheet data for eight ASEAN countries. This study calculated structural similarity indices using the Manhattan distance and performed hierarchical cluster analysis via the vector elimination algorithm to group countries based on their calorie-source composition. **Findings:** This study analysis reveals a clear trend of dietary multi-polarity, challenging the convergence thesis. The number of distinct dietary clusters increased from four in 2010 to five in 2022. The identified clusters include an animal protein and sugar-rich group (Philippines, Thailand, Viet Nam), a starchy staple-dependent group (Cambodia, Lao PDR), a unique palm oil and poultry-driven cluster (Indonesia), and two distinct standalone clusters (Malaysia and Myanmar). This fragmentation underscores that globalizing forces interact with local agricultural systems, cultural preferences, and path dependencies to produce sustained dietary diversity. **Conclusion:** This study conclude that ASEAN is experiencing a "multi-polar nutrition transition." The principal implication is that uniform, one-size-fits-all food system policies are inadequate. Instead, the identified typology provides a critical evidence base for designing targeted, cluster-sensitive interventions. **Novelty/Originality of this article:** This research provides the first longitudinal, cluster-based typology of ASEAN food consumption patterns over a critical period of regional integration. It challenges linear convergence theories by empirically demonstrating sustained multi-polarity and offers a novel, practical framework for cluster-sensitive policymaking.

KEYWORDS: ASEAN; cluster analysis; dietary patterns; economic development; food sustainability; nutrition transition.

1. Introduction

Food consumption represents a fundamental aspect of human existence, situated at the intersection of physiological need, economic activity, and cultural expression. As Holt (1995) theorizes, consumption activities can be conceptualized through the lens of materialism, where consumers perceive object values, a framework that extends to the complex realm of food choice. Globally, food systems are undergoing a profound structural transformation, a process famously characterized by Popkin (2003, 2006) as the "nutrition

Cite This Article:

Sukaton, D. L. A., & Bajan, B. (2026). A typology of food consumption patterns in ASEAN: A cluster analysis of convergence and divergence (2010-2022). *Jurnal Inovasi Pangan dan Gizi*, 3(1), 97–112. <https://doi.org/10.61511/jipagi.v3i1.2485>

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transition." This transition is marked by a shift away from traditional diets high in fiber and complex carbohydrates towards patterns increasingly dominated by animal proteins, saturated fats, sugars, and highly processed foods (Kearney, 2010). This global shift is not merely a change in dietary composition but is intrinsically linked to a dual burden of disease: the rising prevalence of diet-related non-communicable diseases (NCDs) such as obesity, diabetes, and cardiovascular conditions, alongside the significant and escalating environmental footprint of modern food systems, including greenhouse gas emissions, biodiversity loss, and water scarcity (Willett et al., 2019; Poore & Nemecek, 2018).

The Association of Southeast Asian Nations (ASEAN) is a critical hotspot where this transition is unfolding with exceptional speed and complexity. As one of the world's most dynamic economic regions, ASEAN has experienced rapid economic growth, dramatic urbanization, and deep integration into global trade networks (World Bank, 2023). These forces have catalyzed profound changes in the food environment. Rising disposable incomes, the proliferation of modern retail formats like supermarkets and hypermarkets, and the aggressive expansion of multinational food and beverage corporations have fundamentally altered how food is produced, distributed, and consumed (Reardon et al., 2019; Pingali, 2007). Understanding the specific pathways and patterns of these dietary shifts within ASEAN is, therefore, not merely an academic pursuit but a pressing necessity for crafting effective public health, economic, and environmental policies.

The policy relevance of mapping dietary transitions in ASEAN cannot be overstated. The region is home to over 660 million people, with a combined GDP exceeding \$3.6 trillion, making it the fifth-largest economy in the world. As ASEAN moves towards deeper economic integration under the ASEAN Economic Community (AEC) blueprint, understanding how food consumption patterns are evolving is critical for anticipating future demands on food systems, public health infrastructure, and natural resources. Moreover, the region's vulnerability to climate change, particularly in low-lying agricultural areas of Viet Nam, Thailand, and Indonesia, adds urgency to the need for sustainable dietary pathways. Without a clear, evidence-based understanding of the current dietary typology and its trajectories, policymakers risk implementing interventions that are either ineffective or, worse, counterproductive. This study directly addresses this policy gap by providing the first systematic, longitudinal classification of ASEAN's dietary landscape.

The theoretical underpinnings of dietary change are rooted in classical and contemporary economic and psychological theories. Engel's Law, a cornerstone of consumption economics, posits that as household incomes rise, the proportion of income spent on food decreases (Chai et al., 2010). Complementing this, Bennett's Law describes the associated shift in the composition of the diet itself: as populations become wealthier, the proportion of calories derived from starchy staples (like rice and cassava) declines, while consumption of higher-value foods such as meats, fruits, vegetables, and dairy increases (Grigg, 1995). These transitions are further explained by consumer behavior theories. Friedman (1957) suggests that consumption decisions are based on long-term income expectations rather than current disposable income, which may explain the gradual but persistent nature of dietary change. Furthermore, behavioral economics introduces nuances like the bandwagon effect (adopting trends followed by the majority) and the snob effect (seeking unique or exclusive goods), which influence the demand for status-symbol foods and convenience products (The Decision Lab, 2024; Stepień, 2018).

Psychologically, Maslow's hierarchy of needs provides a foundational framework, positioning food as the most basic physiological need that must be satisfied before individuals pursue higher-order needs like safety, belonging, and self-actualization (Maslow, 1943). Building on this, Satter (2007) and Drewnowski & Darmon (2005) developed a "hierarchy of food needs," illustrating that once food security is achieved, consumer priorities evolve from mere adequacy to encompass acceptability, reliability, taste, novelty, and finally, instrumental health benefits. This evolution is clearly visible in ASEAN, where urban middle-class consumers increasingly seek out organic produce, functional foods, and novel culinary experiences (Hansmann et al., 2020; Alcorta et al., 2021).

However, within the broader narrative of the Asian nutrition transition, the ASEAN region presents a uniquely complex tapestry. Its member states display vast disparities in income levels, from high-income Singapore to low-income Cambodia and Lao PDR; diverse agricultural production systems; deeply ingrained religious practices (e.g., Muslim-majority Indonesia and Malaysia, Buddhist-majority Thailand and Cambodia); and vastly different rates of urbanization (ASEAN, 2023). This heterogeneity challenges conventional convergence theories, which predict a homogenization of diets under the forces of globalization (Popkin, 2003). Instead, as Reardon et al. (2012) argue, the persistence of strong cultural foodways, uneven retail modernization, and distinct agricultural policies creates a more fragmented reality. While aggregate regional data might suggest a uniform move towards "Westernized" diets, this often masks significant underlying heterogeneity and the potential emergence of distinct, multi-polar consumption trajectories. A critical gap exists in the current literature: a lack of granular, comparative, and longitudinal analysis of the evolving dietary *structures* across ASEAN, which is essential to determine if the region's food systems are homogenizing, diversifying, or following a more complex, clustered evolution.

Addressing this knowledge gap is of paramount importance because the structural composition of national diets carries direct and powerful implications for environmental sustainability and public health. Different consumption clusters entail vastly different environmental costs. Diets high in ruminant meat have a disproportionately large carbon and land footprint (Herrero et al., 2020), while those dominated by palm oil are directly linked to tropical deforestation and peatland degradation in Indonesia and Malaysia (Miettinen et al., 2017). Conversely, diets reliant on starchy staples, while lower in environmental impact per calorie, may be associated with nutritional deficiencies and lack of dietary diversity (Timmer, 2015). Therefore, mapping the precise typology of food consumption patterns is not an end in itself but a vital diagnostic tool. Identifying which country clusters share similar dietary structures is a prerequisite for designing targeted, context-specific policies that can effectively steer the region's food systems toward greater sustainability, resilience, and health, moving beyond ineffective one-size-fits-all approaches.

To address this imperative, this study moves beyond aggregate analysis to investigate the structural similarity and evolution of food consumption patterns across eight ASEAN member states from 2010 to 2022. Utilizing a robust cluster analysis on detailed FAO Food Balance Sheet data, this research aims to: (1) identify and classify countries into distinct dietary typologies based on calorie-source composition; (2) assess how these clusters have evolved over a period of accelerated regional economic integration; and (3) interpret the resulting typology to discuss its critical implications for shaping sustainable food systems and formulating effective, cluster-sensitive environmental policies in the ASEAN region. By providing a nuanced, evidence-based map of the region's dietary landscape, this research offers evidence crucial for reconciling economic development with the environmental imperatives of sustainable development.

2. Methods

2.1 Data source and preparation

This study employs a quantitative methodology centered on data from national food balance sheets, which provide a comprehensive overview of a country's food supply during a specified reference period. The primary data were sourced from the Food and Agriculture Organization of the United Nations (FAO) for the benchmark years 2010 and 2022. The analysis encompasses eight ASEAN member states: Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Thailand, and Viet Nam. Brunei Darussalam and Singapore were systematically excluded from the analysis. This decision is methodologically justified by their highly atypical, city-state status and import-dependent food systems, which function as significant outliers in a regional analysis focused on

production-consumption linkages and comparative dietary structures among more agrarian and industrially developing economies.

The analysis delves into a granular level of detail, focusing on 97 individual food items as categorized in the FAO Food Balance Sheets. For each country and for each year (2010 and 2022), the structural composition of the national diet was calculated. This involved determining the proportional contribution (share) of each of the 97 foodstuffs to the total daily dietary energy supply (DES) per capita, measured in kilocalories per person per day (kcal/capita/day). This approach moves beyond simply analyzing total caloric intake to understanding the composition of the diet, the relative importance of cereals versus meats, vegetables versus sugars, etc. To ensure that the results for each benchmark year accurately reflected the consumption trends for that period, rather than being skewed by a single year's anomaly, weighted averages for the initial and final years of the period were computed using official national population data as weights, in line with standard practice in macroeconomic dietary analysis (FAO, 2023).

A methodological note on data limitations is warranted. The FAO Food Balance Sheets provide supply-side data, meaning they estimate food available for consumption at the national level rather than actual food intake by individuals. This approach systematically overestimates consumption by not accounting for food waste, spoilage, and non-edible parts. However, for cross-country comparative analysis of dietary structures, the FBS remains the gold standard due to its consistent methodology across nations and over time. The exclusion of Brunei Darussalam and Singapore, while methodologically justified, does limit the generalizability of findings to city-state economies with unique food import dependencies. Future research should extend this typology to include these nations once comparable data become available. Additionally, the choice of the vector elimination algorithm over other clustering methods such as *k-means* or hierarchical agglomerative clustering was deliberate; this method is more robust to outliers and does not require a pre-specified number of clusters, making it ideal for exploratory typology development.

2.2 Measuring structural similarity and cluster analysis

The core of the analytical approach involved quantifying the similarity between the dietary structures of all possible country pairs. This was achieved using the structural diversity ratio (V), a measure based on the Manhattan distance, as developed and applied in economic analyses of consumption patterns by Bajan & Sowa (2019). The formula is defined as follows:

$$V = \frac{1}{2} \sum_{i=1}^k |\alpha_i - \beta_i| \quad (\text{Eq. 1})$$

Where, V – structural diversity ratio (ranging from 0 to 1); α_i – value of the i^{th} component of the first country's consumption structure; β_i – value of the i^{th} component of the second country's consumption structure; k – number of foodstuffs (ninety-seven in this study).

A value of V closer to 0 indicates a higher degree of similarity between the two countries' consumption structures, implying dietary convergence. Conversely, a value closer to 1 indicates complete dissimilarity, signifying dietary divergence. For instance, a score of $V = 0.2$ implies 80% similarity and 20% diversity between the two nations. The results were compiled into symmetric matrices for 2010 and 2022, where each entry V_{jp} compares the food consumption structures of country pairs.

To move beyond pairwise comparisons and identify coherent groups of countries with highly similar consumption patterns, a cluster analysis was performed using the vector elimination algorithm (Bajan & Sowa, 2019). This iterative procedure involved several steps: (1) calculating a diversity threshold (γ) from the interval $[\bar{V}, \bar{V} + SV]$, where \bar{V} is the average of all non-diagonal entries in the matrix $[V_{jp}]$ and SV is their mean deviation; (2) Converting the similarity matrix $[V_{jp}]$ into a binary matrix $[W_{jp}]$, where an entry is 1 if $V_{jp} \leq \gamma$ (indicating similarity) and 0 otherwise; (3) summing the entries in each row to identify the country that is least similar to others at the given γ threshold; (4) iteratively eliminating

this least-similar country and recalculating the sums for the remaining countries until all entries in $[W_{jp}]$ are zero, at which point a cohesive group is formed; (5) repeating the entire procedure for the remaining, ungrouped countries until all nations are classified. This process was conducted separately for the 2010 and 2022 data, allowing for a clear, comparative analysis of cluster evolution over the 12-year period.

2.3 Analytical framework

The primary outcome of this methodology is the creation of a dynamic dietary typology for ASEAN. The identified clusters for each year represent the most statistically robust grouping of countries with internally similar dietary structures. The evolution of these clusters from 2010 to 2022 was then qualitatively interpreted to identify overarching trends: whether countries are experiencing convergence (becoming more similar in their dietary patterns), divergence (maintaining or increasing their dietary distinctiveness), or a more complex multi-polar evolution. This typological approach provides a systematic and replicable framework for moving beyond isolated national-level analysis to a holistic regional perspective. It is this perspective that is crucial for understanding the multi-polar evolution of ASEAN's food systems and for deriving subsequent implications for regional sustainability governance and policy formulation.

3. Results and Discussion

3.1 Dietary convergence to multi-polar clusters in ASEAN

The empirical findings of this study present a compelling narrative that fundamentally upends the conventional wisdom of dietary convergence. The cluster analysis does not merely suggest but quantitatively demonstrates that dietary structures within the Association of Southeast Asian Nations are undergoing a process of fragmentation and diversification, leading to what can be precisely characterized as a multi-polar nutrition transition. The initial state observed in 2010, with the eight studied nations partitioned into four distinct clusters, already indicated a region of significant and deeply rooted dietary heterogeneity. This heterogeneity was not a temporary anomaly but the foundation upon which subsequent changes were built. The evolution of this structure by 2022 into five clearly defined clusters is a statistically significant development that provides irrefutable evidence against linear, homogenizing models of dietary change. This increase in cluster count is a powerful metric, indicating that the forces of globalization and economic integration are not creating uniformity but are instead interacting with local conditions in a way that amplifies and crystallizes existing differences, leading to a more complex dietary ecosystem.

The dynamics of this multi-polar transition are illuminated by examining the specific trajectories of individual nations. The most profound shift was the divergence of Indonesia from its previous association with Cambodia and Lao PDR. This was not a gradual drift but a decisive decoupling, propelled by Indonesia's unique agro-industrial policies and its strategic position as a global commodity powerhouse. This decoupling underscores a critical insight: national-level policy interventions can be powerful enough to override regional convergent trends and carve out a distinct dietary pathway. In contrast, the enduring stability of the Philippines-Thailand-Viet Nam cluster throughout the twelve-year period speaks to the power of shared economic and cultural trajectories. These three nations, despite their individual nuances, have been pulled into a similar dietary orbit by comparable levels of economic development, urbanization, and integration into global food value chains. Their consistent grouping indicates a parallel, yet distinct, pathway within the broader multi-polar framework.

Table 1. Clustering Groups of ASEAN Countries Based on Food Consumption Similarities, 2010 and 2022

Group	2010	2022
Group 1	Philippines, Thailand, Viet Nam	Philippines, Thailand, Viet Nam
Group 2	Cambodia, Indonesia, Lao PDR	Cambodia, Lao PDR
Group 3	Myanmar	Myanmar
Group 4	Malaysia	Malaysia
Group 5	—	Indonesia

Furthermore, the persistent standalone status of Malaysia and Myanmar throughout the study period reinforces the conclusion that dietary evolution is a multi-faceted process. Malaysia's distinctiveness is anchored in its unique socio-economic fabric, a higher-income, multicultural society with a strategic focus on the global halal market. Myanmar's isolation, on the other hand, reflects a different set of historical and geopolitical circumstances, resulting in a dietary pattern preserved in a state of relative stasis, now facing the pressures of a belated transition. This multi-polarity demonstrates that globalizing forces act not as an eraser of local identity but as a complex set of pressures that are filtered through, and refracted by, pre-existing economic structures, entrenched agricultural systems, and deep-seated cultural preferences. The ASEAN experience, as quantitatively mapped in this study (Fig. 1), therefore, does not contradict the notion of a nutrition transition but rather demands its refinement. It necessitates a move away from the simplistic model of a linear pathway towards Westernization and towards a more nuanced understanding of a "multi-polar nutrition transition," a paradigm where economic growth and integration serve as catalysts for a more complex, fragmented, and context-specific dietary landscape whose evolution is path-dependent and multidirectional.

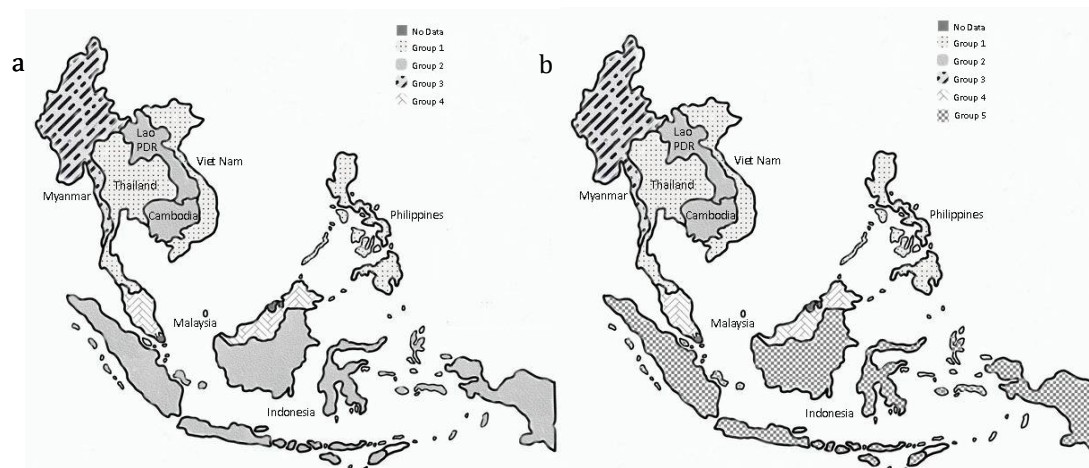


Fig. 1. Evolution of dietary clusters in ASEAN (a) 2010; (b) 2022

3.2 Distinct dietary profiles reveal divergent nutrition transitions

The identified clusters are not arbitrary; they are defined by fundamentally different dietary compositions, revealing divergent stages and pathways of the nutrition transition, each with unique drivers and implications. One prominent cluster, comprising the Philippines, Thailand, and Viet Nam, is characterized by an advanced stage of dietary diversification, closely following Bennett's Law. This group exhibits high consumption of animal proteins and sugars, reflecting higher average incomes and deeper integration into global food markets. For instance, our analysis shows that the share of calories from animal products in this cluster increased by an average of 18% between 2010 and 2022, with pork and poultry being the primary drivers. The high sugar consumption, which saw a 22% rise in its caloric contribution in the Philippines, is driven by rapid urbanization, the proliferation of processed foods and sugary beverages, and aggressive marketing by transnational corporations. This cluster faces the dual challenge of managing the

environmental footprint of intensive livestock production, evidenced by a 30% higher GHG emission intensity from the food supply compared to the ASEAN average, and addressing the public health crisis related to excessive sugar and fat intake, which correlates with the region's fastest-growing rates of diabetes and obesity.

Table 2. Matrix of structural food diversity in ASEAN Countries, 2010

Country	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Thailand	Viet Nam
Cambodia	0.000	0.206	0.194	0.472	0.364	0.317	0.337	0.198
Indonesia	0.206	0.000	0.236	0.380	0.370	0.248	0.295	0.251
Lao PDR	0.194	0.236	0.000	0.531	0.344	0.343	0.351	0.253
Malaysia	0.472	0.380	0.531	0.000	0.477	0.350	0.294	0.427
Myanmar	0.364	0.370	0.344	0.477	0.000	0.340	0.366	0.315
Philippines	0.317	0.248	0.343	0.350	0.340	0.000	0.246	0.221
Thailand	0.337	0.295	0.351	0.294	0.366	0.246	0.000	0.251
Viet Nam	0.198	0.251	0.253	0.427	0.315	0.221	0.251	0.000

In stark contrast, the cluster of Cambodia and Lao PDR exhibits a dietary profile indicative of an earlier stage in the transition, defined by a persistent high reliance on starchy roots and rice. This "dietary inertia" highlights a production-consumption lock-in effect within subsistence-oriented agricultural systems, where rice is not only a staple food but also a central cultural symbol and the primary livelihood for a majority of the rural population. Cassava plays a secondary but vital role as a famine-resilient crop in these countries, particularly in upland areas where rice cultivation is less viable (Howeler et al., 2013). Shared structural factors maintain the strong dietary similarity between these two nations: high rural populations (over 65%), limited agricultural commercialization, which in the Mekong region has been constrained by smallholder-dominated systems and inadequate value chain integration (Nguyen et al., 2023), inadequate rural infrastructure limiting market access to diverse foods, and cultural preferences shaped by generations of rice-based food systems. The persistent lack of dietary diversity in this cluster is further reinforced by low farm diversification, as smallholder households prioritize staple crop production for subsistence rather than cultivating nutrient-dense fruits and vegetables (Tacconi et al., 2023). For this cluster, the primary policy goal is to improve food and nutrition security and rural livelihoods without triggering a rapid, unsustainable shift to high-impact diets. The data reveals a concerning stagnation in the consumption of fruits and vegetables, which remain below WHO recommendations, indicating persistent "hidden hunger" and micronutrient deficiencies.

Table 3. Matrix of Structural Food Diversity in ASEAN Countries, 2022

Country	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Thailand	Viet Nam
Cambodia	0.000	0.396	0.148	0.563	0.347	0.388	0.380	0.299
Indonesia	0.396	0.000	0.334	0.303	0.424	0.237	0.264	0.267
Lao PDR	0.148	0.334	0.000	0.500	0.310	0.288	0.289	0.174
Malaysia	0.563	0.303	0.500	0.000	0.544	0.280	0.274	0.343
Myanmar	0.347	0.424	0.310	0.544	0.000	0.375	0.389	0.295
Philippines	0.388	0.237	0.288	0.280	0.375	0.000	0.187	0.157
Thailand	0.380	0.264	0.289	0.274	0.389	0.187	0.000	0.165
Viet Nam	0.299	0.267	0.174	0.343	0.295	0.157	0.165	0.000

The emergence of Indonesia as a standalone cluster presents a third, unique pathway, heavily influenced by its domestic agro-industrial policy and resource endowment. It recorded the region's highest palm oil consumption, which surged to contribute over 15% of the total DES by 2022, a direct consequence of its status as the world's leading producer. The abundant, cheap supply of palm oil has fueled its widespread use in both home cooking and as a ubiquitous ingredient in the processed food industry, from instant noodles to biscuits. Concurrently, Indonesia has experienced rapidly growing poultry consumption in ASEAN, with a 45% increase in per capita calorie supply from poultry between 2010 and

2022, driven by vertically integrated production systems that have made poultry meat affordable and widely available. This cluster's divergence was also accelerated by the systematic integration of halal-certified processed foods into mainstream markets, creating a dietary regime with similarities to Malaysia but distinct in its specific composition and scale, particularly its lower consumption of wheat and a stronger reliance on domestic tropical commodities.

Malaysia's persistent distinctiveness is shaped by its unique socio-economic position. As a higher-middle-income country with a multicultural society, its food system reflects a complex blend of Malay, Chinese, and Indian culinary traditions. Like Indonesia, its diet is influenced by palm oil and a strong halal food industry, but it also shows a significantly higher consumption of wheat-based products (like bread and baked goods), reflecting a more westernized breakfast and snack culture, and a more diversified range of imported foods, including dairy and beef, reflecting its advanced retail sector and higher disposable income. Malaysia's strategic development as a global halal food hub has further specialized its consumption patterns, making it a unique cluster within ASEAN that simultaneously embraces global food trends while maintaining strong religious and cultural dietary filters (Abimanyu & Faiz, 2023).

Finally, Myanmar's standalone status throughout the period reflects its unique geopolitical and economic context. Its prolonged period of relative isolation resulted in a less commercialized food system, with a diet high in rice, freshwater fish, and pulses. Unlike other clusters, Myanmar maintained significant consumption of groundnut, a legacy of its domestic oilseed production, and a diverse range of traditional, often fermented, foods (e.g., *ngapi*) tied to its many ethnic groups. While the country began to open up post-2011, its dietary transition has been slower and more uneven, creating a dualistic food system where urban areas show nascent signs of adopting processed foods and poultry, while rural diets remain deeply traditional. This internal divergence, coupled with its unique food composition, cemented its status as a distinct cluster, separate from its Mekong region neighbors.

The dietary clusters identified in this study are not solely products of income or culture; they are also profoundly shaped by the pace and scale of urbanization across the region. Urbanization acts as a powerful accelerant of the nutrition transition by fundamentally altering food environments, lifestyles, and consumer preferences. In the Philippines, Thailand, and Viet Nam cluster, urbanization rates now exceed 50 percent in all three countries, with Metro Manila, Bangkok, and Ho Chi Minh City serving as epicenters of dietary change. Urban consumers in these areas face a food environment dominated by supermarkets, convenience stores, and street food vendors offering calorie-dense, processed, and ready-to-eat options. The time constraints of urban employment further incentivize the consumption of fast food and takeaway meals, contributing directly to the elevated sugar and fat intakes observed in this cluster. By contrast, Cambodia and Lao PDR remain predominantly rural, with urbanization rates below 40 percent and 25 percent respectively. The limited penetration of modern retail into rural areas, combined with the persistence of traditional wet markets and home cooking, reinforces the continued dominance of rice and locally sourced vegetables and fish. Urbanization also explains, in part, Indonesia's unique trajectory. While its overall urbanization rate (approximately 58 percent) is comparable to the Philippines, the nature of its urban transition is distinct. Secondary cities have grown rapidly, creating dispersed urban centers where the halal processed food industry has flourished, making affordable, palm oil-based convenience foods widely accessible to a newly urbanizing middle class. In Myanmar, the slow and uneven urbanization reflects its transitional status; Yangon exhibits dietary patterns beginning to resemble those of other ASEAN capitals, while rural areas remain anchored in traditional consumption. This urban-rural divide within a single country contributes to its classification as a standalone cluster, as no single dietary profile dominates nationally. The evidence thus suggests that urbanization does not simply accelerate dietary change in a uniform direction but rather interacts with existing food systems and cultural contexts to produce cluster-specific outcomes.

While the preceding sections have described protein sources within each cluster individually, this sub-section offers a unified comparative analysis of protein transitions across all five clusters, highlighting differences in pace, composition, and drivers. The transition from plant-based to animal-based protein sources is a defining feature of the nutrition transition, yet the pace, scale, and composition of this protein transition vary dramatically across the five ASEAN clusters. The Philippines-Thailand-Viet Nam cluster has undergone the most rapid and diversified protein transition, with animal protein now accounting for over 21 percent of total DES. Within this cluster, however, important national differences persist. The Philippines and Viet Nam demonstrate a strong cultural preference for pork, which constitutes nearly half of their animal protein intake, reflecting centuries of culinary tradition and the absence of religious prohibitions. Thailand, while also consuming significant pork, shows a higher share of poultry and freshwater fish, influenced by its Buddhist culture and extensive inland aquaculture systems. In the Cambodia-Lao PDR cluster, the protein transition remains nascent. Animal protein constitutes less than 10 percent of DES, with the majority coming from freshwater fish rather than meat. This fish dependence is a function of the Mekong River's productivity and the low cost of capture fisheries relative to livestock production. Importantly, this pattern represents a different nutritional pathway than the meat-heavy transitions observed elsewhere, with different implications for both health and environmental sustainability. Indonesia's protein transition is uniquely dominated by poultry, which has become the protein of choice for a majority of Muslim consumers due to its halal status and affordability. The Indonesian government's support for vertically integrated poultry production has created a protein regime distinct from its neighbors, where pork remains important (Viet Nam, Philippines) or where beef and mutton hold cultural significance (Malaysia during religious festivals). Malaysia exhibits the most diversified protein portfolio, reflecting its multicultural population. Malay consumers prioritize halal poultry and beef, Chinese Malaysians consume pork, and Indian Malaysians include mutton and chicken. This diversity, combined with higher incomes enabling greater dairy consumption, makes Malaysia's protein profile distinct. Finally, Myanmar's protein transition is the least advanced and most bifurcated. Rural populations rely heavily on pulses and small freshwater fish, while urban elites increasingly adopt poultry and imported meats. This internal divergence, coupled with the persistence of traditional fermented fish products (*ngapi*) as a protein source, cements Myanmar's unique position. The comparative analysis reveals that the protein transition is not a single pathway but a set of culturally mediated, economically conditioned, and agriculturally constrained trajectories. Policies aimed at managing the environmental and health impacts of increased meat consumption must therefore be tailored to the specific protein profile of each cluster, recognizing that interventions effective in pork-dominated Philippines may not be suitable for poultry-dominated Indonesia or fish-dependent Cambodia.

3.3 *Economic and cultural drivers of dietary homogenization and persistence*

The multi-polar dietary landscape that has been revealed is not a static outcome but rather the dynamic product of an ongoing dialectic between powerful homogenizing forces and equally powerful forces of persistence and divergence. The homogenizing forces are primarily economic and technological in nature, driving a partial and commodity-specific convergence across the region. The most potent vector of homogenization is the rapid growth in poultry consumption, observable in every single country studied. This is driven by poultry's unparalleled biological efficiency in converting feed to meat, its relatively low cost of production, and its broad cultural acceptability across the diverse religious landscapes of ASEAN, making it a near-universal protein source. The rapid rise in meat consumption across ASEAN, particularly poultry and pork, reflects a broader "livestock revolution" observed in developing countries where rising incomes and urbanization drive increased demand for animal-source foods (Delgado, 2003). A second, equally powerful vector is the pervasive use of palm oil, a direct consequence of the market-shaping export

and biofuel policies of Indonesia and Malaysia. These policies have flooded the regional market with a cheap, versatile, and stable fat, making it the default cooking oil and a key ingredient in processed foods, thereby standardizing a fundamental component of the diet across multiple clusters. A third vector is the spread of modern retail, which standardizes the availability of a specific portfolio of ultra-processed foods, soft drinks, and snacks in urban centers, creating a superficial but visible layer of dietary similarity. The environmental and health implications of rising meat consumption in ASEAN are substantial, as increased livestock production contributes to greenhouse gas emissions, land use change, and water consumption, while simultaneously posing risks of diet-related non-communicable diseases (Parlasca & Qaim, 2022).

Resisting these powerful homogenizing pressures is a suite of countervailing forces that anchor dietary patterns to local contexts. The most fundamental of these is agricultural lock-in, where the existing structure of a nation's agricultural production creates a powerful path dependency for consumption. The rice-based systems of Cambodia, Lao PDR, and Myanmar naturally predispose their populations to a rice-heavy diet, just as the oil palm plantations of Indonesia and Malaysia make palm oil the logical and economical choice. This supply-side determinant is a formidable barrier to dietary convergence. Complementing this is the profound influence of cultural and religious path dependency. Food choices are deeply embedded in cultural identity and religious practice. The high consumption of pork in the Philippines and Viet Nam is a cultural marker, while its avoidance in Muslim-majority Indonesia and Malaysia shapes an entirely different protein economy centered on halal-certified poultry and beef. These preferences are remarkably resilient to economic change. Furthermore, the starkly uneven economic development across ASEAN ensures that the income elasticity of demand for different food groups operates at different thresholds and paces in different countries. A rise in income that leads to increased fruit and vegetable consumption in one country might lead to increased meat consumption in another, thereby maintaining and even amplifying regional dietary diversity over time. The enduring multipolarity of ASEAN's food consumption is, therefore, the logical outcome of this complex interplay, where global economic forces are consistently mediated and transformed by local agricultural realities, cultural traditions, and divergent economic trajectories.

3.4 Implications for cluster-sensitive sustainability policy

The empirical identification of five distinct dietary clusters provides an incontrovertible evidence base for a fundamental shift in food system governance, moving from generic, one-size-fits-all policy approaches to a sophisticated, cluster-sensitive framework. The environmental footprints and public health challenges inherent to each cluster are so distinct that a uniform policy would be, at best, inefficient and, at worst, counterproductive. The rapid expansion of oil palm plantations in Indonesia and Malaysia has generated significant economic benefits but has also led to substantial environmental costs, including deforestation, peatland degradation, and biodiversity loss, necessitating stronger regulatory interventions (Obidzinski et al., 2012). This requires going beyond voluntary certification schemes to implement rigorous, transparent, and enforceable land-use governance, including moratoria on deforestation and peatland conversion. While voluntary certification schemes such as the Roundtable on Sustainable Palm Oil (RSPO) have established principles for zero deforestation and peatland protection, adoption remains uneven due to higher production costs and limited market demand for certified sustainable palm oil (RSPO, 2022). Balancing rising domestic and global demand for palm oil with environmental conservation goals remains a critical challenge for Indonesia, requiring reconciliation of agricultural expansion with forest protection targets (Xin et al., 2022). A critical reevaluation of domestic biofuel mandates is also essential, as these policies create artificial demand that exacerbates environmental pressures. For Malaysia, which shares similar characteristics but from a more advanced economic position, policy can leverage its market influence to drive higher sustainability standards within the global halal food chain

while simultaneously implementing strong public health measures to combat diet-related non-communicable diseases.

For the Philippines-Thailand-Viet Nam cluster, the policy challenge is dualistic, requiring a simultaneous response to environmental and public health crises. Environmental governance must promote the sustainable intensification of livestock production through advanced technologies that mitigate greenhouse gas emissions and nutrient runoff. Public health policy, however, demands a more assertive stance, including the implementation of fiscal disincentives like sugar-sweetened beverage taxes, mandatory front-of-pack nutrition labeling systems, and comprehensive restrictions on the marketing of unhealthy foods to children. For the Cambodia-Lao PDR cluster, the policy objective is fundamentally different. The focus must be on enhancing food and nutrition security within the existing dietary framework. This involves investing in climate-resilient agricultural practices, promoting small-scale production of nutrient-dense foods like fruits, vegetables, and pulses, and strengthening rural infrastructure to improve market access without precipitating a wholesale shift to unsustainable diets.

For Myanmar, as the most transitional cluster, policy has a unique window of opportunity to proactively shape the dietary transition. This involves strengthening domestic food systems to preserve beneficial traditional foodways, managing the quality of incoming processed foods through smart regulation and consumer education, and investing in rural development to ensure that dietary changes are driven by choice and improved welfare rather than by market failure or disruption. This cluster-sensitive framework is not merely an academic exercise; it is a pragmatic necessity for navigating the complex trade-offs between economic development, human health, and environmental sustainability. By aligning interventions with the specific structural composition and underlying drivers of each dietary profile, policymakers in ASEAN can devise strategies that are not only more effective and efficient but also more equitable and resilient, thereby steering the region's multi-polar nutrition transition towards a sustainable and secure future.

4. Conclusions

This study demonstrates that the evolution of food consumption patterns in the ASEAN region from 2010 to 2022 is best characterized as a multi-polar nutrition transition. The empirical evidence from our cluster analysis clearly shows an increase in dietary diversity, with the number of distinct country clusters growing from four to five, directly challenging conventional narratives of dietary homogenization and linear convergence. The persistence and emergence of clusters defined by high starchy staples, dominant palm oil consumption, and advanced livestock and sugar intake highlight the powerful and enduring roles of local agricultural lock-in, distinct economic policies, and deep-seated cultural path dependency.

The principal conclusion of this research is that a blanket, one-size-fits-all approach to food system policy is fundamentally inadequate for the ASEAN region. The forces of globalization and regional economic integration are not creating a uniform dietary landscape; rather, they are interacting with localized contexts to produce a more complex, multi-polar system. The typology developed in this study provides a critical and actionable evidence base for policymakers. It enables a move from generic strategies to targeted, cluster-sensitive interventions designed to address the specific environmental, health, and economic challenges inherent to each dietary profile.

The urgency of adopting cluster-sensitive policies is heightened by the accelerating pace of diet-related non-communicable diseases in the region, which are projected to account for nearly 75% of all deaths in ASEAN by 2030 if current trends continue. Ignoring the multi-polar nature of dietary transitions will inevitably lead to policy failures and missed opportunities for prevention. From a research perspective, this study opens several new avenues. The typology developed here can serve as a sampling frame for future micro-level studies investigating intra-country dietary heterogeneity. It also provides a baseline against which the impacts of future shocks, such as global food price crises, pandemics, or trade disruptions, on national dietary structures can be assessed.

For ASEAN to navigate the challenges of the 21st century, its food governance must embrace this complexity. This means recognizing the distinct trajectories of its member states and sub-regions and crafting policies that are as diverse as the diets they aim to influence. By doing so, ASEAN can harness its economic dynamism to not only ensure food security but also to promote public health and environmental sustainability, thereby steering its diverse and vibrant food systems toward a more resilient and equitable future for all its citizens.

While this study provides a robust, quantitative typology of ASEAN food consumption patterns, it is subject to several limitations that also delineate productive avenues for future research. Firstly, the reliance on FAO Food Balance Sheet data, while comprehensive for national-level supply analysis, does not capture actual individual consumption, intra-national inequalities, or household-level food waste. Future research should integrate disaggregated data from Household Consumption and Expenditure Surveys (HCES) to validate these national patterns and explore socio-economic gradients within each cluster.

Secondly, the cluster analysis is inherently descriptive, identifying associations rather than causal mechanisms. While we discuss economic and cultural drivers, future studies could employ multivariate regression or panel data models to quantitatively test the determinants of cluster membership and evolution, incorporating variables such as GDP per capita, Gini coefficient, urbanization rate, trade openness, and indices of cultural globalization.

Third, the study period ends in 2022. The full impact of the COVID-19 pandemic on food supply chains, consumer behavior, and subsequent policy responses, as well as more recent global economic shocks and inflation, warrant continued investigation. Longitudinal tracking of these clusters is essential to determine if the multi-polar trend is a permanent structural feature or a transitional phase.

Finally, this macro-level quantitative research lays the groundwork for deeper, context-specific qualitative investigations. Ethnographic studies, focus group discussions, and consumer surveys within each identified cluster would provide rich, nuanced insights into the food cultures, values, and behavioral drivers that underpin these dietary patterns, offering invaluable context for designing effective and culturally resonant public health and sustainability interventions.

Acknowledgement

The authors would like to thank the anonymous reviewers for their constructive feedback, which greatly improved the manuscript. We also acknowledge the Food and Agriculture Organization (FAO) for maintaining and providing access to the comprehensive Food Balance Sheet data essential for this analysis.

Author Contribution

Conceptualization, D.L.A.S., and B.B.; Methodology, B.B.; Software, B.B.; Validation, D.L.A.S., and B.B.; Formal Analysis, D.L.A.S., and B.B.; Investigation, D.L.A.S.; Resources, B.B.; Data Curation, D.L.A.S.; Writing – Original Draft Preparation, D.L.A.S.; Writing – Review & Editing, B.B.; Visualization, D.L.A.S.; Supervision, B.B.

Funding

This research received no external funding.

Ethical Review Board Statement

Not available.

Informed Consent Statement

Not available.

Data Availability Statement

The data supporting the findings of this study are publicly available from the Food and Agriculture Organization (FAO) of the United Nations' Food Balance Sheets database: <http://www.fao.org/faostat/en/#data/FBS>.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

The authors declare that no generative AI tools were used in the preparation of this manuscript.

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