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MORALITY BEFORE KNOWLEDGE

Stakeholders, strategy, and staple diversification: A game-theoretic analysis of food security policy

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ABSTRACT

Background: Food security is a strategic priority for Indonesia, yet the country has not fully capitalized on its abundant natural resources. Its 2022 Global Food Security Index (GFSI) score was only 60.2 (ranked 63rd of 113 countries), and 8.53% of the population still experiences undernourishment (Prevalence of Undernourishment). Food policymaking is fragmented because stakeholders hold divergent interests and time horizons, making it a *wicked problem*. Staple diversification was chosen as the case study because it is backed by a legal framework, but its implementation is hindered by entrenched rice-consumption culture and misaligned programs. **Methods:** This study combines bibliometric analysis (keywords "food security", "policy", "game theory" and "public policy", "game theory") with game theory modeling. Four players were modeled: government, producers, consumers, and academics. Each chooses between Cooperating and Maintaining the Status Quo. Of the 16 possible scenarios, those categorized as failures were pruned. Feasible scenarios were assigned qualitative utilities (scale of -3 to +3) for short-term (ST) and long-term (LT) outcomes, then analyzed using Nash equilibrium, Pareto dominance, and ST-greedy behavior. **Findings:** Full cooperation (C, C, C, C) is the only Nash equilibrium that is stable in both the short and long term. Implementation occurs only when government, producers, and consumers are aligned in the short term. Producers act as the main bottleneck, while academics are structurally disempowered because they do not determine implementation success. "Mutate" outcomes represent realistic partial success, and ST-greedy equilibria are often insufficient. **Conclusion:** Staple diversification succeeds only when short-term incentives are aligned across sectors. Recommendations include targeted short-term incentives, prioritized support for producers, consumer engagement, adaptive implementation frameworks, and academic partnerships. **Novelty/Originality of this article:** This study applies multi-actor game theory with ST and LT horizons to Indonesia's staple diversification policy, a topic that remains rarely examined in the literature. Its contributions include a payoff matrix as a policy-design tool and new insights into the roles of academics and producers.

KEYWORDS: food security; food diversification; game theory; Indonesia; public policy.

1. Introduction

Food security is one of the most fundamental priorities for any nation. Defined as existing when "... all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (Food and Agriculture Organization (FAO), 1996), food security is essential not only for the survival of its population but also for a country's strategic autonomy—enabling resilience in times of crisis and contributing to broader geopolitical stability. Indonesia, richly endowed with natural resources and ecological diversity, possesses the geographic

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and agricultural capacity to, in theory, sustain its population for generations. In many ways, Indonesia mirrors the fictional Ironborn of Westeros—proud, insular, and fiercely tied to its archipelagic identity and natural wealth. Yet despite these blessings, like the Ironborns, Indonesia remains largely peripheral on the world stage: lacking coordinated influence, hesitant to pursue structural reform, and internally fragmented. This contradiction becomes clearer when viewed through the four dimensions of food security: affordability, availability, quality and safety, as well as sustainability and adaptation. According to the Global Food Security Index (GFSI), Indonesia scored 60.2 in 2022, ranking 63rd out of 113 countries (The Economist Intelligence Unit, 2022). While this is a respectable mid-range score, it falls short of expectations for a nation with such abundant resources. More concerning is the Prevalence of Undernourishment (PoU), which shows that 8.53% of Indonesia's population still consumes less than the minimum daily requirement of 2,100 kcal per capita for a healthy, active life (*Badan Pangan Nasional*, 2024). The irony is stark: abundance without leverage, potential without power.

This irony can be traced to the complex and often fragmented nature of public policy formation in Indonesia, particularly in sectors involving multiple, interdependent stakeholders. In the case of food security, the key actors include national and regional governments, private sector entities within the food industry, academic researchers, agricultural producers, and end-consumers. Each of these groups brings divergent interests, priorities, and timelines to the table. The result is limited coordination and the frequent production of policies that are inconsistent, unsustainable, or ineffectively implemented. For example, from the academic perspective, scholars in sustainable development often advocate for a shift away or the coined term food diversification from rice dependency and toward staple crops more ecologically aligned with Indonesia's native environment such as sago, cassava, and breadfruit (Rahmanto,et. al., 2020; Hardono, 2016). Despite the clear sustainability rationale, such proposals frequently face cultural resistance and lack political will (Ariani & Ashari, 2016).

Simultaneously, policies like Makan Bergizi Gratis—intended to address stunting among children—highlight how targeted interventions can unintentionally disrupt broader food security strategies (Dwijayanti, 2024). These initiatives may divert funding and institutional focus away from potentially more effective, long-term solutions, creating policy trade-offs that are rarely accounted for (Fatimah, et. al., 2024). Another persistent challenge lies in the economic mismatch between consumers and producers: while nutritious foods remain costly for consumers, farmers receive disproportionately low compensation, deepening rural poverty and disincentivizing sustainable agricultural practices (Salasa, 2021; Ilham, et. al., 2006). Moreover, existing agricultural policies often mandate the cultivation of non-native crops, to preserve Indonesia's food culture, particularly its reliance on rice. While culturally significant, this approach undermines environmental sustainability by promoting low-efficiency, high-input crops ill-suited to local conditions, thereby reducing energy efficiency and weakening long-term conservation goals (Marwanto & Pangestu, 2021; Rasman, et. al., 2023).

Wicked problems—those characterized by complexity, uncertainty, and competing values (Rittel & Webber, 1973) such as policymaking for food security, especially in the face of climate change, require innovative approaches to generate effective solutions. Game theory offers a fresh lens for understanding the dynamics between stakeholders, framing them as players with distinct motivations and possible courses of action, operating within a shared game where the objective is to formulate effective food security policies. This paper aims to explore how stakeholder interactions in Indonesian food security policymaking can be modeled using a game theory matrix, and to determine whether a Nash equilibrium exists—where each stakeholder selects an optimal strategy given the strategies of others. Identifying such an equilibrium could point to a policy outcome that, while not necessarily perfect, is stable and mutually acceptable. In addition, the resulting payoff matrix may serve as a useful tool for shaping policy recommendations that align with Indonesia's current economic and political landscape.

2. Methods

This study employs a game theory approach to model the interactions between stakeholders involved in food security policymaking in Indonesia. Game theory, originally formalized by John von Neumann and Oskar Morgenstern in Theory of Games and Economic Behavior (1944), is the study how interacting agents make strategic decisions that lead to specific outcomes. At its core, game theory examines strategic interactions between rational agents—referred to as players—each of whom must choose among a set of possible actions or strategies. The combination of these strategies leads to specific outcomes, which are assigned utility values based on the preferences of each player. Depending on these outcomes, players may adjust their strategies to maximize their benefit or minimize their losses. In public policy analysis, this framework enables a structured understanding of how stakeholders with differing priorities and constraints navigate interdependent decision-making processes. Game theory has since evolved from a mathematical framework into a widely used analytical tool across fields such as economics, international relations, and public policy (Osborne & Rubinstein, 1994; Myerson, 1991). In policymaking, game theory can serve as a theoretical framework for analyzing strategic interactions among rational agents, where the outcome (policy/impact) depends not only on their own choices but also on the choices of others.

To better understand the intersection between game theory and public policy, a bibliometric analysis was conducted. This analysis aimed to map the academic landscape surrounding the use of game theory in policymaking and, more specifically, in food security. Keyword combinations used included “food security” + “policy” + “game theory” (n = 20 documents), and “public policy” + “game theory” (n = 345 documents).

The keyword network analysis (Figure 1) reveals that game theory is a well-established framework in public policy research, with clusters of work focusing on subtopics such as environmental regulation, sustainable development, and to a lesser extent, food security. Notably, food security appears as a relatively smaller node in the network, suggesting a niche but growing area of interest. Further examination of key publications shows that high-impact studies often apply game theory—particularly evolutionary game models—in the context of renewable energy policy.

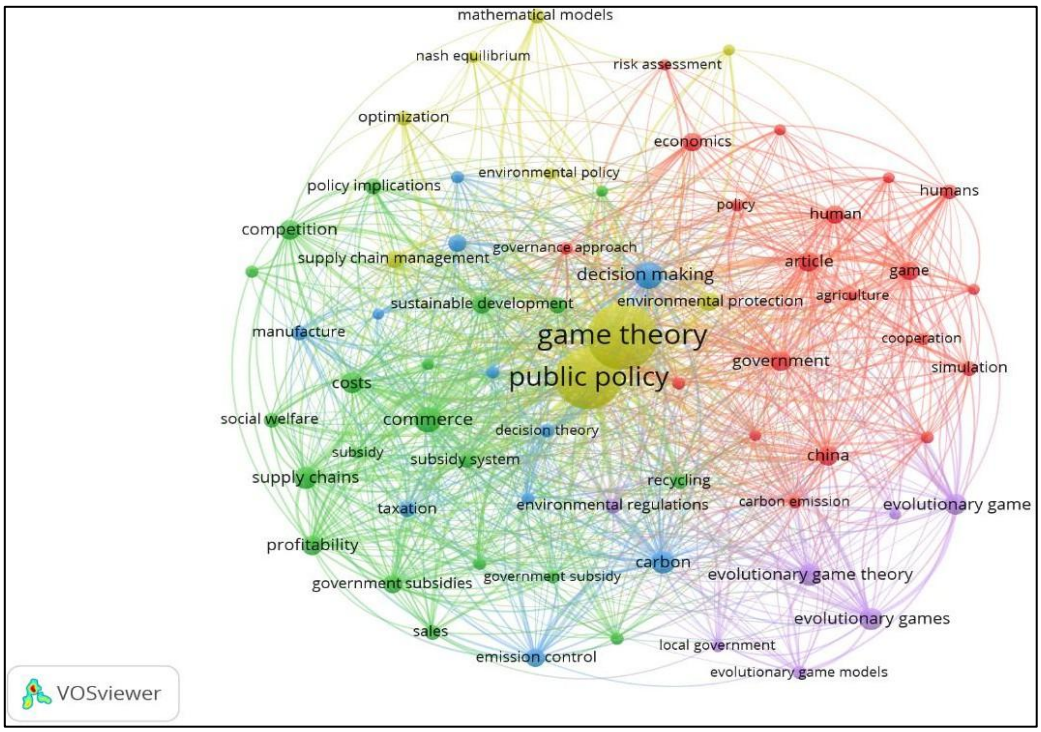

Fig. 1. Network analysis by keyword
(Author, 2025)

The density map by country (Figure 2) indicates that research on game theory and public policy has been gaining traction since 2014, especially in Western countries such as the United States and the United Kingdom. More recently, countries like China and Iran have also entered this research space, with increasing output observed from the early 2020s onward.

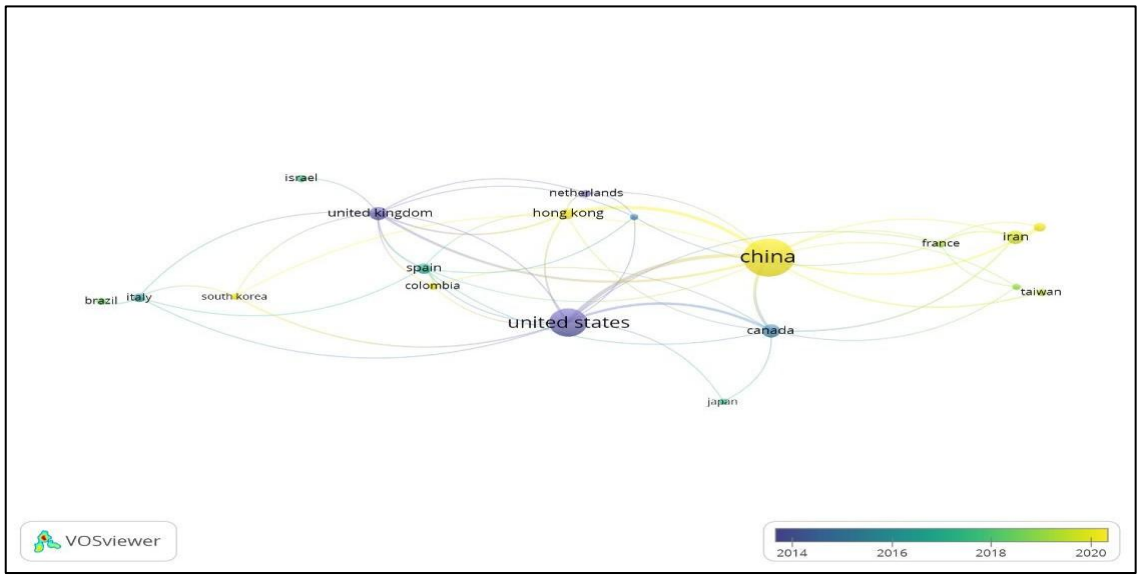

Fig. 2. Density analysis by country
(Author, 2025)

Following the bibliometric groundwork, this study proceeds to model real-world stakeholder dynamics in Indonesian food security policymaking using a simplified game theory framework. Drawing from selected case studies, policy documents, and stakeholder reports, a stylized payoff matrix will be constructed to represent the strategic interactions among key actors—namely, national and regional governments, private food sector entities, agricultural producers, and consumer groups. For this paper, the "*Diversifikasi Pangan*" or "Staple Diversification" strategy is chosen as the case study to be analyzed.

Each stakeholder will be framed as a "player" in the game, with a discrete set of possible actions based on their observed or inferred policy preferences and constraints. Payoffs will be assigned qualitatively based on likely outcomes of each combination of actions, considering factors such as sustainability, economic feasibility, and political acceptability. The resulting payoff matrix will be analyzed to determine whether a Nash equilibrium exists—i.e., a scenario in which no stakeholder has an incentive to deviate from their chosen strategy given the strategies of others (Nash, 1950). In this context, such an equilibrium would reflect a strategically stable policy configuration—one that, while not perfect, may represent the most viable pathway toward resolving Indonesia's food security puzzle.

3. Results and Discussion

3.1 Strategy staple diversification

Staple diversification/*diversifikasi pangan* is a critical strategy for achieving food and nutrition security in Indonesia. Historically, Indonesian diets have been dominated by rice, creating vulnerabilities in food systems due to monoculture dependence (Salasa, 2021). Diversification aims to promote alternative staples such as cassava, maize, sago, and sweet potato, which are more adaptable to diverse ecological zones and often more nutritious.

Government frameworks have supported this agenda, notably UU No. 18 Tahun 2012, which emphasizes food that is diverse, nutritious, safe, and culturally appropriate (GoI, 2012). Strategic efforts like Perpres No. 22/2009 and the urban poverty alleviation

program/*Program Penanggulangan Kemiskinan di Perkotaan* (P2KP) program sought to enhance dietary diversity and support local food production. The National Food Agency/*Badan Pangan Nasional*, established in 2021, now coordinates policies related to staple diversification, highlighting its strategic importance (*Badan Pangan Nasional*, 2023).

Despite the clear rationale and policy support, implementation has faced persistent challenges. On the consumption side, several factors have impeded progress: strong cultural norms favor rice consumption (*belum makan kalau belum makan nasi*); rice's affordability and availability; limited income that prevents dietary alternatives; and weak infrastructure for processing and marketing non-rice staples. Moreover, overlapping policies—such as rice subsidies for the poor—unintentionally reinforce rice dominance (epublikasi.pertanian.go.id). Government tolerance of wheat imports and aggressive advertising of instant noodles have also contributed to urban dietary shifts toward wheat, rather than local staples (Neliti, 2015). As a result, traditional staples like sago and maize have been increasingly marginalized, even in regions where they were once daily fare.

On the production side, large-scale diversification attempts such as food estate programs have historically underperformed. From the 1950s to recent years, food estate initiatives in Kalimantan, Papua, and Sumatra often failed due to poor planning, site mismatches, land conflicts, and low farmer readiness (Rasman et al., 2023). These projects, aimed at boosting staple output, frequently lacked environmental assessments and community involvement. Some resulted in deforestation, peatland drainage, carbon emissions, and biodiversity loss—ironically undermining the sustainability they sought to support. These failures underscore that diversification is not simply a matter of top-down policy but requires grounded, participatory approaches that align ecological conditions with farmer capacity and cultural practices.

3.2 Game theory analysis to policymaking stakeholders

3.2.1 Defining the actions

Each stakeholder has two primary actions to choose from in the context of this policy: Cooperating or Maintaining the Status Quo. Cooperation implies that the stakeholder actively supports and engages in efforts to implement staple diversification, whereas maintaining the status quo means the stakeholder resists or does not actively engage with the policy, preferring to continue their existing behavior.

Cooperating: This action reflects a willingness to support the policy and work collaboratively with others to achieve its goals. For the government, this could involve providing incentives or funding; for producers, adapting crop production; for consumers, shifting dietary habits; and for academics, conducting research and providing evidence to support the policy.

Status Quo: This action reflects resistance to or disengagement from the policy. It can manifest in the form of producers continuing to grow traditional crops, consumers refusing to adapt to new food staples, or governments failing to allocate necessary resources. The possible actions can be expressed as the following group:

$$Ax = \{Cooperating, Status\ Quo\} \quad \text{(Eq. 1)}$$

where (Ax) represents the set of possible actions available to actor (x), consisting of two alternatives: Cooperating and Status Quo. Cooperating refers to an action in which the actor actively supports the policy and collaborates with other stakeholders to achieve its objectives, whereas Status Quo refers to an action in which the actor maintains existing practices or refrains from supporting the proposed policy.

3.2.2 Defining the stakeholders

The analysis centers on four primary stakeholders, each having short-term (ST) and long-term (LT) preferred outcomes (Table 1): a) Government (G): The government plays a crucial role in creating an enabling environment for the policy. Its actions are typically driven by short-term political considerations and long-term goals for national food security, economic stability, and sustainable development; b) Producers (P): Agricultural producers are vital players since they control the supply of staple crops. Their willingness to diversify crops depends on incentives, market conditions, and the perceived benefits of policy changes; c) Consumers (C): Consumer behavior is influenced by preferences, cultural norms, and economic factors. Their willingness to adopt new staples can determine the policy's success or failure in the long run; d) Academics (A): Academics contribute to the evidence base supporting the policy. While their influence on practical implementation may seem limited, their research can be instrumental in providing data on the long-term sustainability and potential benefits of staple diversification. The stakeholders can be expressed as the following group:

$$x = \{Government, Producers, Consumers, Academic\} \quad \text{(Eq. 2)}$$

where (x) represents the set of stakeholders involved in policy implementation, comprising the Government, Producers, Consumers, and Academics. The Government refers to public institutions responsible for formulating, implementing, and supporting the policy through regulations, incentives, and resource allocation. Producers are agricultural producers responsible for adapting crop production and supporting food diversification. Consumers are individuals or households whose consumption preferences and dietary choices influence the adoption of alternative food staples. Academics refer to researchers and academic institutions that provide scientific evidence, research, and recommendations to support policy development and implementation.

Table 1. Player preferences

Player (x)	Short-Term Preference (ST)	Long-Term Preference (LT)
Govt	Political stability, public image, ease of implementation	National food resilience, sustainable systems
Producers	Market certainty, profit, ease of production	Resilient agriculture, stable supply chains
Consumers	Price & availability, convenience	Affordable, nutritious food; future stability
Academics	Policy impact, system transformation	Climate change mitigated, sustainable development

Each stakeholder's utility can be captured in a utility function such that:

$$Ux(A) = (STx, LTx) \quad \text{(Eq. 3)}$$

where $Ux(A)$ represents the utility of stakeholder (x) under the action profile (A), while (STx) and (LTx) denote the stakeholder's short-term and long-term utility, respectively. The utility function therefore captures the benefits or outcomes experienced by each stakeholder in both the short-term and long-term perspectives.

3.2.3 Mapping all possible scenarios

The matrix (Table 2) explores all possible scenarios where each stakeholder either cooperates (C) or maintains the status quo (S) in relation to the staple diversification policy. Each combination of strategies leads to different outcomes, ranging from successful policy implementation to failure or stagnation. By mapping these interactions, we identify the

conditions under which cooperation among stakeholders is most likely to succeed, and the risks associated with each potential outcome.

Table 2. All possible scenarios

Scenario	Govt	Prods	Consm	Acads	Narrative Summary	Category
1	C	C	C	C	All players support staple diversification. Gov provides incentives, producers diversify crops, consumers adapt diets, academics support policy with research. Initial costs but long-term resilience and stability.	Implemented
2	C	C	C	S	All but academics support the policy. Implementation goes forward, but lacks critical research/evaluation, leading to inefficiencies or knowledge gaps.	Implemented
3	C	C	S	C	Consumers reject the new staples. Policy gets partial traction; producers bear cost without full market support. Possible backlash.	Stall
4	C	C	S	S	Top-down push with no consumer or research support. High risk of policy failure or inefficiency.	Fail
5	C	S	C	C	Gov pushes policy, consumers are willing, but producers don't adapt. Supply doesn't meet demand, policy stalls.	Stall
6	C	S	C	S	Gov and consumers push for change, but no producer or academic backing. Price spikes or supply mismatches.	Mutate
7	C	S	S	C	Only gov and academics onboard. No producers = no implementation.	Fail
8	C	S	S	S	Gov goes it alone. Likely dead-on-arrival policy. No uptake or practical traction.	Fail
9	S	C	C	C	Producers, consumers, and academics want it, but no gov support = no formal structure or funding. Community-led efforts, but limited scale.	Stall
10	S	C	C	S	Grassroots traction, but lack of institutional support and research. Vulnerable to collapse.	Fail
11	S	C	S	C	Producers and academics want it, but no demand or policy. Investment wasted.	Fail
12	S	C	S	S	Only producers trying = costly, unsustainable without support.	Fail
13	S	S	C	C	Consumers and academics want it, but no supply or policy. Frustrated demand.	Stall
14	S	S	C	S	Only consumers onboard. Preference doesn't change supply.	Fail
15	S	S	S	C	Academics pushing, but no traction elsewhere.	Fail
16	S	S	S	S	Everyone maintains status quo. No change, risks remain.	Control

To focus on scenarios where the food security policy is feasible, we then prune the scenarios which are categorized as fails (Table 3).

Table 3. Feasible scenarios

Scenario	Govt	Prods	Consm	Acads	Narrative Summary	Category
1	C	C	C	C	All players support staple diversification. Gov provides incentives, producers diversify crops, consumers adapt diets, academics support policy with research. Initial costs but long-term resilience and stability.	Implemented
2	C	C	C	S	All but academics support the policy. Implementation goes forward, but lacks critical research/evaluation, leading to inefficiencies or knowledge gaps.	Implemented
3	C	C	S	C	Consumers reject the new staples. Policy gets partial traction; producers bear cost without full market support. Possible backlash.	Stall
5	C	S	C	C	Gov pushes policy, consumers are willing, but producers don't adapt. Supply doesn't meet demand, policy stalls.	Stall
6	C	S	C	S	Gov and consumers push for change, but no producer or academic backing. Price spikes or supply mismatches.	Mutate
9	S	C	C	C	Producers, consumers, and academics want it, but no gov support = no formal structure or funding. Community-led efforts, but limited scale.	Stall
13	S	S	C	C	Consumers and academics want it, but no supply or policy. Frustrated demand.	Stall
16	S	S	S	S	Everyone maintains status quo. No change, risks remain.	Control

3.2.4 Assigning utility values

To quantify the outcomes of each scenario, we developed a categorical scale to assign utility values based on the benefits and costs each stakeholder experiences. This scale helps to simplify the complexity of stakeholder preferences and outcomes, allowing for easier comparison and analysis. The scale is as follows:

Table 4. Qualitative utility scale for stakeholder benefits and costs (−3 to +3)

Score	Category	Description
+3	Big Benefit	A highly favorable outcome that provides substantial positive gains for the stakeholder.
+2	Moderate Benefit	A noticeably positive outcome that provides meaningful benefits, although less significant than a big benefit.
+1	Minor Benefit	A slightly positive outcome that provides limited but favorable effects for the stakeholder.
0	Neutral	An outcome that produces neither significant benefits nor adverse effects for the stakeholder.
-1	Minor Cost	A slightly negative outcome that results in limited adverse effects for the stakeholder.
-2	Moderate Cost	A considerably negative outcome that imposes substantial disadvantages on the stakeholder.
-3	Big Cost	A highly unfavorable outcome that results in significant losses or adverse consequences for the stakeholder.

Once the categorical scale was established, we applied the utility values to each feasible scenario in our matrix (Table 5). For each combination of actions taken by the stakeholders (Government, Producers, Consumers, and Academics), we assessed the outcomes and

assigned corresponding utility values based on the expected benefits or costs for each player.

Table 5. Utility values added

Scenario (G, P, C, A)	ST Tuple (Gov, Prod, Cons, Acad)	LT Tuple (Gov, Prod, Cons, Acad)	Outcome
(C, C, C, C)	(+2, +1, 0, +2)	(+3, +3, +3, +3)	Implemented
(C, C, C, S)	(+2, +1, 0, 0)	(+2, +2, +2, +1)	Implemented
(C, C, S, C)	(-1, -1, +1, +1)	(+1, +1, 0, +2)	Stall
(C, S, C, C)	(-1, +1, 0, +2)	(+1, -1, +1, +2)	Stall
(C, S, C, S)	(+1, +1, 0, 0)	(+1, -1, +2, 0)	Mutate
(S, C, C, C)	(0, 0, +1, +2)	(0, +1, +1, +2)	Stall
(S, S, C, C)	(0, 0, +1, +2)	(0, -1, +1, +2)	Stall
(S, S, S, S)	(+1, +2, +2, -1)	(-2, -2, -2, -2)	Control

3.2.5 Identifying Nash Equilibrium

In the context of multi-actor interaction between Government, Producer, Consumer, and Academic stakeholders, the scenario (C, C, C, C) represents both a short-term and long-term Nash equilibrium. In the short term, each actor receives non-negative and relatively favorable payoffs (ST: +2, +1, 0,+2), and any unilateral deviation would result in a worse outcome for the deviator. Long-term payoffs further reinforce this configuration, with each actor obtaining a maximum of +3, reflecting optimal synergy. As no player has incentive to deviate in either horizon, this scenario is both strategically stable and fully implemented.

Other scenarios, while occasionally implemented in the short term (e.g., (C, C, C, S)), tend to feature actors—such as the Academic in this case—with incentives to deviate due to reduced LT payoffs (+1 vs. +3 if cooperating). Several scenarios like (C, C, S, C) or (C, S, C, C) result in "Stall" conditions, characterized by fluctuating or suboptimal short-term payoffs (e.g., negative values for Government and Producer) and uncertain long-term benefits. In "Mutate" scenarios such as (C, S, C, S), although some short-term rewards are positive, long-term payoffs reveal inconsistencies and potential for strategy shifts—indicating instability. The most volatile case, (S, S, S, S), categorized as "Control", delivers initially high short-term benefits for some but leads to universally negative long-term outcomes (−2 for all actors), underscoring the unsustainability of full defection.

Overall, only (C, C, C, C) demonstrates the characteristics of a strong, sustainable equilibrium—both short-term optimality and long-term convergence—while other scenarios fall into categories of transitional or unstable dynamics, making them unsuitable for consistent implementation.

3.2.6 Identifying other realistic algorithms

3.2.6.1 Pareto dominance

An outcome of a game is Pareto dominated if some other outcome would make at least one player better off without hurting any other player. That is, some other outcome is weakly preferred by all players and strictly preferred by at least one player. In this case, we choose scenarios which have non-negative utility values in both short-term (ST) and long-term (LT) cases.

Table 6. *Pareto dominance*

Scenario (G, P, C, A)	ST (G, P, C, A)	LT (G, P, C, A)	Outcome	All Non-Negative?
(C, C, C, C)	(+2, +1, 0, +2)	(+3, +3, +3, +3)	Implemented	Yes
(C, C, C, S)	(+2, +1, 0, 0)	(+2, +2, +2, +1)	Implemented	Yes
(C, C, S, C)	(-1, -1, +1, +1)	(+1, +1, 0, +2)	Stall	No (ST: G, P)
(C, S, C, C)	(-1, +1, 0, +2)	(+1, -1, +1, +2)	Stall	No (ST: G, LT: P)
(C, S, C, S)	(+1, +1, 0, 0)	(+1, -1, +2, 0)	Mutate	No (LT: P)

(S, C, C, C)	(0, 0, +1, +2)	(0, +1, +1, +2)	Stall	Yes
(S, S, C, C)	(0, 0, +1, +2)	(0, -1, +1, +2)	Stall	No (LT: P)
(S, S, S, S)	(+1, +2, +2, -1)	(-2, -2, -2, -2)	Control	No (ST: A, LT: all)

3.2.6.2 ST-Greedy

Another approach is to prioritize the greedy short term utility values for each playter to mimic real-world behavior of preferring short-term gratifications over long term and collective benefit. An ST-greedy choice is considered if it gives a player maximum ST utility, and considered not ST-greedy if they could get more utility by switching strategies.

Table 7. *ST-Greedy*

Scenario (G, P, C, A)	ST (G, P, C, A)	Outcome	ST-Greedy?
(C, C, C, C)	(+2, +1, 0, +2)	Implemented	VVVV
(C, C, C, S)	(+2, +1, 0, 0)	Implemented	VVVV
(C, C, S, C)	(-1, -1, +1, +1)	Stall	XXVV
(C, S, C, C)	(-1, +1, 0, +2)	Stall	XVVV
(C, S, C, S)	(+1, +1, 0, 0)	Mutate	VVVV
(S, C, C, C)	(0, 0, +1, +2)	Stall	VVVV
(S, S, C, C)	(0, 0, +1, +2)	Stall	VVVV
(S, S, S, S)	(+1, +2, +2, -1)	Control	VVVX

3.2.7 Insights

The simulation reveals several critical insights about the dynamics of policy implementation in the context of staple diversification, especially when considering the interaction of four key stakeholders: government, producers, consumers, and academics. Although long-term (LT) benefits are often positive for all actors, implementation occurs only when short-term (ST) incentives are aligned underscoring the dominant influence of ST utility, particularly for government and producers, on policy viability.

3.2.7.1 Policy implementation relies on cross-sector ST alignment

The success of staple diversification policy hinges on short-term cooperation from at least three actors: the government, producers, and consumers. Even when long-term utilities are high across the board, implementation is not guaranteed unless ST payoffs also align positively. Notably, the role of academics in implementation appears marginal; their support, while valuable for legitimacy or knowledge production, does not influence the success of implementation in a decisive way: a) government support emerges as a necessary condition for success. It plays a critical role in shaping the policy environment through incentives, regulation, and agenda-setting. Scenarios show that when the government defects, policy failure is almost guaranteed highlighting its gatekeeping function; b) consumer acceptance is equally crucial. No matter how favorable the policies are, they cannot succeed without public buy-in. If consumers are unwilling to shift their dietary preferences or adopt new staples, implementation stalls. This is evident in scenarios where consumer defection directly correlates with policy failure; c) producers occupy a pivotal position. While not as visible as government or consumers, producers serve as a tipping point. Their resistance often leads to “Stall” or “Mutate” outcomes even when other actors cooperate. This shows that producer behavior must be actively managed through tailored incentive structures especially when transitioning toward climate-oriented or sustainability-driven policies.

This suggest that implementation only occurs when government, producers, and consumers are all aligned in the short term. Rational actors seeking ST utility can still produce socially desirable outcomes, but only under specific, carefully aligned conditions.

3.2.7.2 Academics are structurally disempowered

In nearly all configurations, academic cooperation or defection has no decisive impact on whether a policy is implemented. While academics often favor long-term systemic change, their short-term preferences are usually out of sync with other actors. As a result, in ST-greedy environments, they tend to defect not because they oppose the policy, but because their utility is low. This reflects a deeper structural disempowerment in the policy ecosystem, where academic inputs are undervalued unless directly incentivized. Strengthening the academic-policy interface may require mechanisms to increase their ST utility (e.g., recognition, funding, co-design roles).

3.2.7.3 Producer behavior is a bottleneck

The simulation reveals that producers hold disproportionate leverage. When they defect, it disrupts the entire implementation chain even if other actors are aligned. This implies that any real-world attempt to implement staple diversification (or similar food system transitions) must prioritize producer incentives and concerns. Risks such as producer lag in climate-related transitions must be addressed through proactive strategies.

3.2.7.4 Mutate outcomes reflect real-world partial success

In scenarios like (C, S, C, S), the policy does not fully succeed but transforms or mutates into a partial implementation. These mutate outcomes mirror real-world phenomena such as policy drift, market distortions, or emergent adaptations that do not align with the original design but still yield progress. Understanding these hybrid results can inform discussions on second-best solutions and adaptive governance, where even suboptimal cooperation can generate momentum.

3.2.7.5 ST-greedy equilibria are often insufficient

While short-term equilibria may seem stable, they frequently fail to lead to policy implementation or produce poor long-term outcomes. This reveals the limitations of relying solely on short-term logic in policymaking. To address this, coordinated interventions are required to bridge the gap between short-term utility and long-term goals. Examples include: a) short-term subsidies or risk-sharing schemes for producers; b) behavioral campaigns to shift consumer preferences; c) policy-academic partnerships that integrate academic actors into implementation in ways that also benefit them in the short term.

3.2.8 Food security policy recommendations

While the staple diversification strategy is well-supported by legal and institutional frameworks (e.g., UU No. 18 Tahun 2012, Perpres No. 22/2009), its practical implementation has been hindered by fragmented short-term incentives, weak cross-sector alignment, and the underutilization of local food resources. Insights from simulation highlight that policy success relies heavily on short-term (ST) cooperation between the government, producers, and consumers, whereas academic support, although valuable for long-term sustainability, holds limited influence in triggering implementation.

To address these structural and behavioral barriers, we recommend the following: align short-term incentives across stakeholders the government must provide targeted, short-term incentives for producers and consumers to adopt and promote alternative staples. This can include: Input subsidies for cassava, sago, and other local crops; Guaranteed purchase schemes or price floors; Consumer awareness campaigns to reshape perceptions about non-rice staples.

Institutionalize producer support as a priority given the producer's pivotal role in determining implementation outcomes, policies should: Offer transition packages for

farmers shifting from rice to diversified staples; Strengthen rural processing and storage infrastructure to support market access; Build capacity through extension services tailored to local agroecological contexts.

Engage consumer and encourage mindset shift consumers are one of the key stakeholders that drives policy implementation success, therefore should be the focus in getting their approval on board. Efforts should be made to encourage and engage consumers in making better, more diverse food choices which in turn would shift demand for other stakeholders.

Create adaptive implementation pathways recognize that some diversification efforts may not fully succeed immediately, but can "mutate" into partial progress or other more relevant or acceptable policies. Encourage adaptive policy frameworks that allow for learning, community customization, and feedback loops.

Leverage long-term framing through academic partnership although academics are structurally weak in short-term influence, their contribution is vital for long-term outcomes. Policies should integrate research institutions in implementation monitoring, local food system design, and innovation testing — ideally with ST benefits such as grants, recognition, or pilot programs.

4. Conclusions

Staple diversification is a vital strategy to strengthen Indonesia's food and nutrition security. While the policy is well-supported in principle, its success in practice hinges on short-term alignment among key stakeholders—particularly the government, producers, and consumers. Deep-rooted cultural preferences, fragmented incentives, and inconsistent implementation have undermined progress. Simulation insights confirm that policy implementation is unlikely without cross-sector cooperation in the short term, even when long-term benefits are clear.

The path forward is clear: targeted short-term incentives, producer-focused support, and consumer engagement must be prioritized. Government leadership is essential to create a coordinated, adaptive policy environment that bridges immediate motivations with long-term goals. Now is the time to act—to transform staple diversification from policy ambition into a resilient, people-centered reality.

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Author Contribution

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Informed Consent Statement

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Data Availability Statement

The data supporting the findings of this study are available within the article. Further inquiries regarding the data can be directed to the corresponding author.

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The author declares no conflicts of interest.

Declaration of Generative AI Use

Generative AI tools were used solely to assist with language refinement and grammatical editing. All research concepts, data analysis, interpretations, findings, and conclusions were developed and verified by the author, who takes full responsibility for the content of this manuscript.

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