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Indonesia's Palm Oil Trilemma: Reconciling Biodiesel Expansion, Export Competitiveness, and Supply Resilience under Climate and Governance Constraints

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ABSTRACT

Indonesia's palm oil sector is being asked to serve an expanding domestic energy market while sustaining food and oleochemical supply, export competitiveness, rural livelihoods, and ecological integrity. This interpretive qualitative literature review examines the resulting policy trilemma using peer-reviewed research published during 2020-2026 and the IPOSS fourth-quarter 2026 industry outlook as a contextual, explicitly prospective source. The analysis differentiates observed evidence from institutional forecasts, policy announcements, and conceptual scenarios. It synthesises eight interconnected themes: stock-flow consistency; biodiesel allocation and fiscal costs; climate-related production lags; smallholder yield gaps and replanting; commodity pricing and fiscal instruments; welfare distribution; deforestation-related market governance; and adaptive policy coordination. The synthesis indicates that additional domestic biodiesel demand can support energy substitution while raising the opportunity cost of exports and the exposure of levy-financed incentives to commodity price cycles. Weather risks, delayed biological yield responses, constrained smallholder finance, and traceability demands further limit simple supply-side solutions. We propose an integrated decision architecture combining equivalent-unit physical accounting, reserve and food-security safeguards, risk-sensitive biodiesel support, productivity-led expansion without deforestation, and inclusive market access. Five conditional scenarios clarify where policy complementarities are possible and where trade-offs remain unavoidable. The analysis does not claim new econometric estimates or validate IPOSS forecasts. Rather, it identifies measurable policy thresholds, evidence limitations, and a research agenda for jointly assessing energy security, trade value, public finances, farmer welfare, and ecological boundaries.

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Introduction

A Shifting Allocation Problem in the World's Largest Palm Oil Producing Economy

Oil palm occupies an unusual position in Indonesian development: it produces internationally traded vegetable oils, supports processing and export earnings, provides income for producers and workers, and supplies an expanding biofuel programme. Because these demands draw on interconnected feedstock streams, a policy that succeeds by one indicator can weaken performance elsewhere. Increasing the share of diesel blended with palm-based fatty-acid methyl esters may substitute for imported petroleum products, but it can also raise domestic requirements for palm-derived inputs when production is constrained. Similarly, restricting exports may conserve physical supply while reducing foreign exchange and the levy receipts that help fund strategic programmes. International research warns against treating commodity expansion, energy substitution, and forest outcomes as separate questions, because governance and land-use responses can shift environmental and economic costs across borders and actors [1-4].

A further distinction concerns the environmental footprint of palm oil relative to alternative vegetable oils. Although oil palm is highly productive per hectare, high land-use efficiency does not neutralise emissions and habitat loss where new plantations replace native vegetation. A cross-commodity appraisal must therefore compare realistic alternatives and enforce land-use safeguards rather than imply that one fuel or crop is intrinsically sustainable [5].

The IPOSS (2026) Outlook Industri Sawit Indonesia Q4 2026 offers a particularly timely contextual account of these tensions. Its annual scenario projects approximately 52.4 million tonnes of combined crude palm oil and palm kernel oil production, around 27.1 million tonnes in domestic consumption, and 25.76 million tonnes of exports expressed in the report's product classification. It envisages year-end inventories of approximately 1.7 million tonnes, following much tighter stocks at selected points during the second half of the year. These are author-reported projections rather than verified 2026 outcomes, and the physical components do not necessarily share the same product-equivalent definitions. The analytical task is consequently to interpret the report's directional stress signals while separating unit conventions, historical data,

assumptions and projected end-year levels. Model-based literature similarly emphasises that allocation consequences depend on conversion factors, initial stocks, demand responses and policy implementation rather than the nominal blending percentage alone [6-8].

The temporal context also matters. The Ministry of Energy and Mineral Resources (2026) reported the launch of the B50 biodiesel mandate in July 2026, but neither a launch announcement nor an industry forecast by itself establishes achieved nationwide volumes, the full composition of eligible production, or an annualised feedstock balance. The 2026 outlook anticipates a particularly consequential transition from partial-year implementation towards a full-year requirement in 2027, conditional upon policy continuity and technical delivery. Assessing that transition requires a distinction between the policy level, the actual biodiesel consumed, the palm-oil-derived feedstock required to manufacture it, and the fraction receiving financial support. Energy-sector reviews describe the long policy evolution towards higher blends and identify the need to examine fuel quality, operational performance, supply capacity and price conditions jointly rather than equating announced targets with completed outcomes [9].

Scarcity, Resilience and Competing Objectives

Supply resilience cannot be assumed merely because oil palm is a perennial crop. Fresh-fruit-bunch formation involves biological stages extending far before harvest, while current rainfall, extreme heat, drought, fire and disrupted roads can alter current operations and the realised distribution of future yields. The IPOSS document interprets an exceptionally dry 2026 episode and associated El Niño-related risks as reasons to strengthen spatially differentiated monitoring. Such claims are valuable for scenario design, yet location-specific exposure and the intensity of meteorological anomalies require independent verification if they are to be asserted as observed fact. Research into delayed water-related yield responses supports a multi-period perspective and cautions against inferring a precise production loss next year from one season's climatic indicators [10-12].

An additional constraint is the slow conversion of agronomic potential into national output. Independent growers have heterogeneous tree ages, planting materials, fertiliser practices and access to credit, advice or formal land documents. Replanting may increase yield in later years but initially removes productive palms and exposes households to a prolonged income gap. Conversely, interventions that improve existing management can raise performance without waiting for a new rotation, although their outcomes still depend on soil and management baselines. Field research on yield gaps, nutrient imbalances, smallholder risk and replanting indicates that the supply-side strategy must be deliberately sequenced rather than inferred from hypothetical hectares multiplied by aspirational yields [13-16].

Research Gap, Questions and Contribution

Studies of palm biodiesel often concentrate on energy substitution and fiscal costs, whereas agricultural studies examine yield gaps, certification or climate exposure and trade studies focus on prices and levies. This specialisation leaves an important synthesis problem: domestic energy allocations, export receipts, levy-funded incentives, crop responses, and market-access obligations interact within one commodity system. A benefit that is robust under abundant stocks may cease to be attractive after an adverse harvest, a wider biodiesel-diesel reference-price spread, or a loss of market access. Methods for evaluating agricultural trade-offs underline why impacts must be considered jointly, across stakeholders and timescales, instead of adding isolated headline benefits [17,18].

This article asks eight linked questions about changing palm-oil allocation, the economic conditions supporting biodiesel, climate-related resilience, productivity-led replanting, price and fiscal transmission, macroeconomic distribution, traceability and tenure, and adaptive policy design. Its objective is to formulate an integrated, empirically interpretable framework that can reconcile these pressures without claiming a unique optimum from insufficient data. The novelty is the explicit combination of primary-oil-equivalent stock-flow accounting, export opportunity costs, multi-period crop biology, farmer inclusion and risk-sensitive governance in a conditional decision sequence. This qualitative literature review does not create new national forecasts, and it maintains a clear separation between peer-reviewed evidence and the IPOSS scenario that motivates the policy discussion [19-21].

Literature Review

A Stock-Flow-Consistent Reading of Food, Energy and Exports

A commodity balance is an accounting identity before it becomes a behavioural or political claim. At a consistent level of processing, ending stocks equal starting stocks plus production and imports, less domestic utilisation, exports and net adjustments. However, palm-sector statistics often report palm fruit, crude palm oil, palm kernel oil, refined fractions, oleochemicals and biodiesel in different units or processing stages. Simple addition of all those numbers risks counting one unit of primary oil several times as it moves through refining, esterification and domestic sales. A defensible analysis first selects a reference commodity, defines transformation yields, separates CPO from PKO unless explicit equivalence rules are appropriate, and notes any unobserved losses or stock adjustments. Dynamic systems research on Indonesian biodiesel demonstrates why apparently small discrepancies in mass conversion, system boundary and timing change conclusions about allocation tightness.

The meaning of an export share also changes with its denominator. The IPOSS figure that domestic utilisation represents approximately 51.3% of combined domestic-plus-export allocation should not be mistaken for 51.3% of all oil-palm production, nor interpreted as a fixed national food-security requirement. Where exports include processed products, their primary-oil content must be reconstructed to establish resource competition; where biodiesel is measured by fuel volume, the necessary feedstock mass depends on process yields and blending definitions. These safeguards help distinguish a genuine supply deficit from a reporting mismatch. They also make the analysis more useful to policy makers who must decide whether to change a blending rule, release inventories, adjust other domestic allocations or permit price-mediated imports and exports.

Biodiesel Mandates, Energy Economics and Public Finance

Biodiesel policy can create industrial demand, foster import substitution and generate learning in domestic fuel processing. Such benefits, however, are not equivalent to a net social gain at every blending ratio. Market incentives depend on fossil-diesel prices, the biodiesel cost formula, exchange rates, feedstock availability, taxes, transport requirements, engine compatibility and the opportunity value of palm oil in alternative sales channels. Earlier evaluations of Indonesia's biodiesel ambitions found that the macroeconomic proposition is sensitive to modelling assumptions. More recent empirical work identifies short-run associations with growth but also diminishing gains at higher

mandate levels and a potential interaction between biodiesel absorption and foregone CPO export opportunities.

The financing dimension creates a distinctive feedback loop. Export levies may fund incentives or other palm-development programmes, but their proceeds fluctuate with prices, taxable product mixes, tariff schedules and export volumes. At the same time, funding needs may grow with an enlarged eligible biodiesel volume and a wider reference-price gap between biodiesel and petroleum diesel. The apparent paradox is that stronger domestic use can increase potential programme expenditure while compressing the export base from which some finance is collected. This does not guarantee insolvency: high oil prices may reduce the incentive gap, rate changes may alter collections and existing fund balances may buffer shocks. It does mean that policy evaluation requires a transparent stress test rather than a single assumed breakeven price [22].

The food-versus-fuel debate is therefore a question of marginal allocation, not a universal rule that either energy or food is intrinsically preferable. Palm products perform different functions in food manufacturing, oleochemistry and fuel blending, and their price transmission may affect consumers, refineries, traders and growers unevenly. A model that treats all these markets as one inelastic sink may exaggerate scarcity, while a model assuming instant reallocation can conceal technical or institutional limits. System-dynamics studies supply useful scenario logic, but their parameters and predicted values should be seen as model results, not substitute observations of policy impacts.

Climate, Delayed Production Response and Adaptive Agronomy

Climate affects palm production through several linked pathways. Drought and rising vapour-pressure deficit can change plant water status, photosynthesis and reproductive processes, while heat, smoke, fire and flooded transport routes may impede harvesting or logistics immediately. Crucially, yield observed in a given month reflects earlier stages of inflorescence initiation, sex differentiation, abortion, bunch development and fruit filling. Consequently, the effect of a severe dry spell need not appear only in the following quarter, and it is unsafe to attribute a contemporaneous national production forecast mechanically to one ENSO index. Multi-year oil-palm field analyses find lagged relationships between water-related conditions and yield, whereas climate-smart agronomy research identifies both potential management adaptations and limits to their effectiveness.

Climate resilience also has a spatial distribution. A country-level seasonal forecast may coexist with highly divergent rainfall and water-storage conditions across Riau, Central Kalimantan, South Sumatra and other producing locations. The IPOSS Q4 2026 outlook uses a production-versus-drought exposure matrix to prioritise areas where substantial palm output may coincide with climatic stress. This is a defensible screening design, provided that a province's quadrant is not mistaken for a measured production loss, a hydrological assessment or a prediction of next year's yield. Locally calibrated indicators should combine rainfall departures, groundwater or peat water level where relevant, soil moisture proxies, fire exposure, palm age, transport continuity and production records. Such layering prevents national planning from confusing ecological hazard with economic exposure and reduces the risk of indiscriminate interventions [23].

Smallholder Yield Gaps, Replanting and Land-Sparing Claims

Productivity-led growth is attractive because it appears to relieve supply scarcity without new plantation area. Indonesian studies nevertheless show large differences between potential and realised smallholder yields, linked to agronomy, nutrient supply and farm-specific management. This creates a real opportunity for better fertilisation, maintenance and harvesting practices; it also warns that potential-yield estimates cannot be applied uniformly to every location or interpreted as instantly achievable. Studies of current smallholder nutrient balances and management interventions offer stronger grounds for realistic improvement targets than sectoral averages. The scale of such gains depends on access to appropriate advice, fertiliser markets, reliable seeds, farmer organisations and the ability to implement management changes consistently.

Replanting involves a different intertemporal trade-off. Replacing poorly performing palms with higher-quality planting materials can improve longer-term supply but reduces production during establishment and creates credit and livelihood needs. Farmers may rationally postpone replanting when land status is unclear, replacement inputs are expensive, or family consumption depends on regular fresh-fruit-bunch sales. Evidence from the Ophir scheme and broader replanting reviews suggests that collective action, trustworthy partners and financing design are often as important as the biological characteristics of seedlings. Remote-sensing and agronomic scenarios also caution against assuming that replanting alone will prevent national supply decline on the policy timetable [24].

Finally, increased yield does not automatically translate into avoided deforestation. If high returns induce additional investment or if land rights are unresolved, intensification may coexist with further expansion. Moreover, drainage on peat or conversion of forests can impose climate and biodiversity damages that are not compensated by higher production per hectare. Research on carbon-rich forest conversion, landscape restoration, the consequences of certification and the limits of biodiversity trade-offs argue for explicit land-use safeguards. Productive rehabilitation of legally established plantations should be distinguished from expanding into valuable natural habitat, and claims about land sparing require evidence on land-use response rather than an assumed one-for-one offset [25-28].

Historical land-cover evidence further shows why intensification must not be equated with an observed conservation outcome. A nationwide satellite-based study linked reduced Indonesian deforestation during the late 2010s to slower oil-palm expansion and weaker prices, while reporting different historical forest-conversion patterns for industrial and smallholder plantations. Those results pertain to 2001–2019 and cannot validate 2026 forecasts; they nonetheless strengthen the case for monitoring actual land conversion when evaluating a productivity-led strategy [29].

Prices, Export Levies and the Distribution of Trade Value

International benchmarks, futures markets, domestic reference prices, transaction costs and public charges interact to determine the value received by different palm-industry participants. Spot and futures markets can communicate expectations but may experience variable liquidity and incomplete price discovery. Prediction studies using financial or machine-learning methods are valuable methodological comparisons, yet forecast accuracy over one test window does not establish that a quoted fourth-quarter price will occur. The economically meaningful export netback must consider

product-specific reference prices, export levies, export duties, shipping, quality and financing, while distinguishing transfers within Indonesia from genuine resource costs. Evidence on market efficiency, price prediction and liquidity therefore informs the appraisal of market institutions without endorsing any single forecast as a fact [30-33].

Export taxes and levies have different legal and fiscal functions, and their incidence may not rest entirely on the formal exporter. Depending on bargaining, conversion costs and domestic market concentration, some charges may be reflected in the fresh-fruit-bunch price received by growers or in refiner margins. Research on Indonesian palm-oil derivatives and certification economics shows why gross export value, fiscal receipts, farmgate income and overall welfare must be evaluated separately. Tariff changes may encourage downstream processing while also reducing raw-export incentives, but causal effects should not be inferred from the rate schedule without comparing product mixes and counterfactual market conditions [34,35].

Traceability, Legitimacy and the Politics of Market Access

Market access increasingly depends on whether companies and producers can demonstrate lawful and deforestation-free sourcing, rather than only the physical availability of oil. Emerging due-diligence rules require geolocation, risk assessment, evidence management and credible responsibilities across traders, mills, collectors and farms. Experience with certification and jurisdictional programmes demonstrates that formal compliance may be uneven and costly, especially among independent smallholders. Research on Indonesia's zero-deforestation commitments shows that producers may be geographically connected to compliant value chains yet receive little traceability training, meaningful market information or price reward [36,37].

Comparative work on the EU Deforestation Regulation (EUDR) highlights that compliance is constructed through organisational processes, buyer interpretations and contested distributions of responsibility. Research in coffee and cocoa is useful for understanding due diligence but cannot be mechanically treated as evidence about Indonesian palm-mill traceability. Land disputes, weak documentation and uncertain tenure remain separate constraints that can prevent the generation of credible sourcing records or discourage investment in farms. Legitimacy therefore requires combining enforceable deforestation safeguards with accessible, privacy-conscious farmer registration, transparent grievance mechanisms and proportionate technical assistance [38,39].

Institutional quality has consequences for household welfare and environmental effectiveness. Some certification schemes improve organisational capacity or selected social indicators, but outcomes vary by scheme, context and the costs borne by producers. Formal participation alone does not show that smallholders receive adequate prices or that deforestation risks have been eliminated. Evidence on certification premiums, smallholder barriers, welfare, market inclusion and the adoption of oil-palm agroforestry suggests that investment in agency and capability is indispensable: farmers must be able to understand rules, secure their land access, negotiate terms and pursue viable livelihoods. A policy architecture focused exclusively on auditing documents may fail precisely where implementation capacity is most scarce [41-45].

Broader synthesis of the oil-palm boom finds substantial private income and employment benefits alongside environmental losses, reinforcing the need for an explicitly distributional evaluation. These competing effects are not adequately represented by a certificate count or an aggregate export value, and policy tests should report both the households that benefit and the ecological assets potentially affected.

Methods: An Interpretive Qualitative Literature Review Design, Case Boundary and Review Logic

This paper uses an interpretive and integrative qualitative literature review (QLR), not a systematic literature review, bibliometric mapping or meta-analysis. Its purpose is to explain how distinct but connected bodies of scholarship illuminate the emerging Indonesian palm-oil policy trilemma. The principal unit of synthesis is a proposition with its contextual conditions: for example, whether a biodiesel mandate supports energy security under particular oil-price assumptions; whether yield improvements can expand national capacity within the timing of the replanting cycle; or whether traceability requirements improve market access without excluding independent growers. Conceptual integration rather than statistical exhaustiveness is appropriate because the literatures employ different measures, research designs, horizons and geographical boundaries. The design takes lessons about transparency and competing objectives from methodological trade-off reviews without claiming the comprehensiveness or pooled effects of systematic synthesis.

The geographic focus is Indonesia, the analytical anchor is the IPOSS fourth-quarter 2026 outlook, and the temporal scope of academic literature is 2020-2026. The IPOSS (2026) report is an industry outlook containing a mixture of historical series, estimated values, model projections, regulatory descriptions and forward-looking interpretations. It is treated as a contextual scenario document rather than one of the 55 peer-reviewed studies. Official government communications may be used to document the announced or implemented B50 policy, while the relevant EU institutional guidance provides the regulatory setting for EUDR; neither source is reclassified as academic evidence. This separation allows the paper to interrogate forecast assumptions without presenting scenario values as independently observed national statistics. Comparisons with other countries or commodities enter only where they illuminate mechanisms whose external validity to Indonesia is discussed explicitly.

Source Selection and Qualitative Appraisal

The preliminary article pool was guided by the Stage 1 framework and the eight research questions, covering palm oil production, biodiesel policy, agricultural intensification, climate exposure, price transmission, export levies, trade governance, land rights, traceability and environmental outcomes. Priority was assigned to peer-reviewed research published between 2020 and 2026 that directly addresses Indonesia, followed by sector-relevant international research, studies of comparable supply chains and methodological papers useful for interpreting the competing objectives. Searches by topic, author and DOI helped establish a traceable reading set; the final manuscript includes only entries that are cited in its main text. The selection is purposive, and no claim is made to a complete database census, exhaustive screening or PRISMA-compliant inclusion counts. DOI URLs are supplied for identification and access, although some publisher full texts require subscriptions.

For each claim, appraisal considered four dimensions: evidence proximity, research design, comparability of measured outcomes, and uncertainty in temporal or institutional transfer. A multi-year Indonesian oil-palm field study is more directly relevant to palm

yield management than a general agroforestry synthesis, while a credible palm-biodiesel fiscal model may be more informative about incentive stress than general claims about renewable energy. Likewise, interview-based EUDR findings in coffee are treated as governance analogies, not as evidence that palm oil has identical compliance costs. Apparent conflicts between studies are retained and explained instead of averaged away: a nature-based practice may improve soil attributes without improving yield, and a certification scheme may improve documentation while delivering modest farm-level price benefits [46,47].

Thematic Coding, Accounting Discipline and Scenario Construction

The first coding layer mapped evidence into eight themes identified in Stage 1: physical balance, biodiesel economics, climate effects, PSR and agronomy, prices and levies, welfare impacts, governance, and policy coordination. The second layer coded mechanisms, affected parties, timescales, and the strength or limitations of evidence. Cross-theme synthesis sought both complements and contradictions: a supply-enhancing intervention may also create a short-run production trough; an export levy may provide revenue while weakening the export netback; a traceability requirement may protect market credibility while raising fixed compliance costs. These contrasts generated five conditional scenarios rather than projected probabilities. Each scenario is defined by direction-of-change assumptions that could later be quantified with harmonised administrative and commercial data.

The accounting framework is deliberately restrictive. It requires a consistent primary-oil-equivalent unit within each balance; reconciliation of CPO and PKO streams; conversion factors for refined products, oleochemicals and biodiesel; and an explicit adjustment item when available series cannot be harmonised. No oil-equivalent export balance or implied growth rate is calculated from unlike products. Similarly, discussions of biodiesel finance distinguish programme-eligible volume, observed price differences, export levy revenue and reserve balances from hypothetical scenarios. The study does not estimate causal coefficients, forecast El Niño losses, perform an original cost-benefit model or independently audit the IPOSS statistical data. Its findings should therefore be interpreted as policy propositions and qualified cross-literature inferences, not newly observed treatment effects.

Results: Eight Thematic Findings

A Narrowing Allocation Cushion Is a Conditional, Not Absolute, Scarcity Signal

The first thematic finding is that the IPOSS scenario depicts a structural change in allocation, with domestic consumption growing faster than overall primary oil production and product exports becoming an important adjustment margin. The report projects annual 2026 production near 52.4 million tonnes, compared with approximately 27.1 million tonnes of domestic utilisation and 25.76 million tonnes of exports in the report's separate product categories. It describes an illustrative fall in export volumes from the prior year and an unusually small stock cushion at selected points during the second half of 2026. The source's narrative is informative about perceived tightness, but these projected product-series numbers should not be forced into a validated mass balance until production and export streams have been harmonised. In particular, the reported 51.3% domestic share is an allocation share with a specified denominator, not proof that precisely half of domestic primary-oil output is consumed by energy users.

The economic significance of stocks is more subtle than their annual closing value. Inventory can smooth fluctuations when production peaks do not match factory needs or shipping schedules, but maintaining very low stocks exposes the system to harvest interruption, fuel delivery shocks or export commitments that cannot easily be deferred. The IPOSS monthly diagram reports a projected low of around 0.3 million tonnes for October and recovery to about 1.7 million tonnes in December, conditional on a seasonal production rebound and lower exports. Those values should be read as scenario stress points, not realised measured availability or an independently established national security threshold. The relevant research question is how many weeks of different types of demand can be met from commercially accessible, usable stocks at varying locations and stages of processing. Figure 1 presents the accounting boundaries and adjustment levers needed before such a claim can be tested.

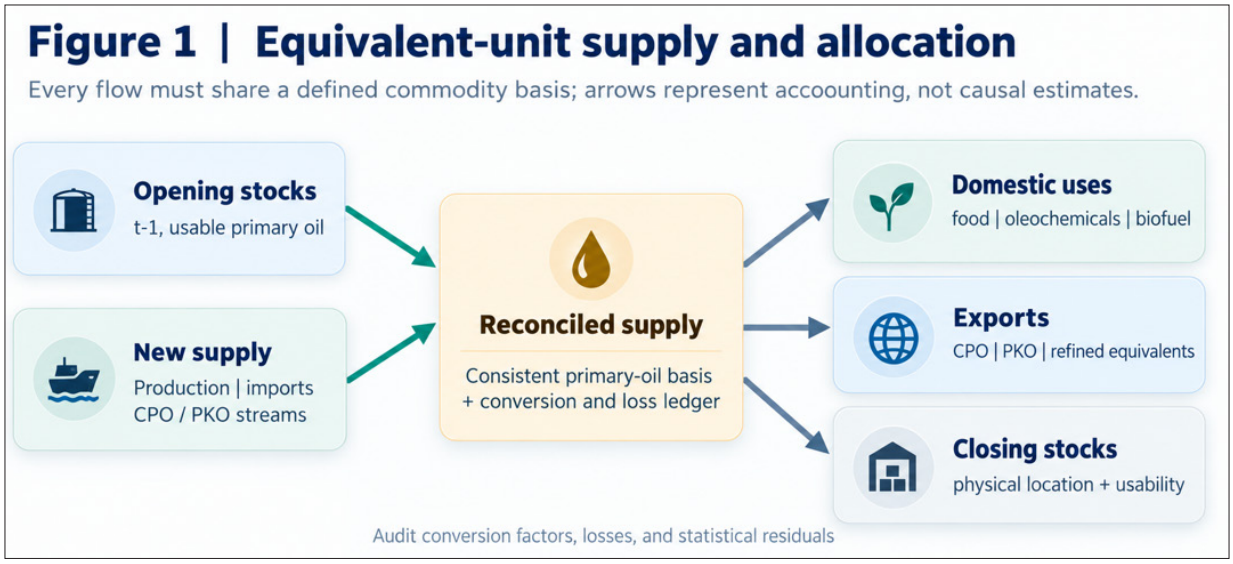


Figure 1: Stock-flow Consistent Physical Palm-Oil Balance and Allocation Levers

Figure 1 clarifies why four decisions that appear similar can have different effects: a larger crop increases the available primary-oil supply, an inventory release changes its timing, greater biodiesel use alters the demand composition, and an export restriction changes where the value is realised. The feedback links indicate possible price and fiscal responses, not estimated causal coefficients. Before applying the identity, an analyst must specify whether the quantity is measured as CPO, PKO or a declared primary-oil equivalent and must keep refined product exports from being counted as additional unprocessed supply. The framework therefore establishes an accounting test that logically precedes policy optimisation.

The Biodiesel Programme Links Energy Substitution to Export Opportunity Costs

The second finding is that domestic energy security and foreign-exchange performance are linked but not mechanically opposed. Government statements document a July 2026 B50 programme launch, and the IPOSS outlook places greater domestic biodiesel demand at the centre of its projected allocation change. Yet a blend designation does not directly specify tonnes of CPO consumed; the relevant demand also depends on diesel sales, actual blended volumes, biodiesel composition, esterification yields and eligibility rules. A higher blend can reduce petroleum-derived diesel use while encouraging new processing activity, but the value of substitution must be compared with foregone alternative palm sales, any additional feedstock imports, distribution costs and the cost of supplying the blending incentive. Historical evaluations and modern trade-off studies support this balanced interpretation rather than a binary pro- or anti-biofuel conclusion.

The literature also suggests that marginal returns matter more than the headline blend target. Where fossil-diesel reference prices are high relative to biodiesel, the incentive requirement may decline; where petroleum prices fall or palm input prices rise, the financial gap can widen. The IPOSS report includes sensitivity illustrations built around a hypothetical full-year B50 biodiesel volume and a range of reference-price gaps. Such arithmetic illustrates exposure, but the result cannot be treated as an audited forecast of actual BPDP receipts or 2027 obligations. Export prices, levy brackets, cash balances, policy exemptions, product mixes and the schedule of disbursements must also be considered. In aggregate, the evidence favours monitoring an energy-security gain together with trade, fiscal and food-market opportunity costs instead of relying on a single measure of fossil-fuel displacement.

Climate Risk Acts Through Immediate Operations and Delayed Biological Pathways

The third finding is a mismatch between the short policy horizon and the long biological response of oil palm. The IPOSS outlook highlights strong El Nino conditions, potential Indian Ocean Dipole effects, drought exposure and elevated fire risks as scenario hazards in late 2026. The report's spatial screening identifies large producing provinces whose production could be material to national supply if drought is prolonged. These observations motivate prudent monitoring, but a national index, monthly rainfall map or hotspot count is not itself an estimate of tonnes of palm oil lost. Yield responses reflect plant age, past climate, inflorescence development, current harvest accessibility and agronomic practice. A production trough attributed only to weather may also reflect replanting, access or management transition, so empirical attribution must be multi-factorial.

Field studies emphasise that stress conditions can affect yields with different delays across reproductive stages, while practical adaptation may protect specific processes without eliminating climatic exposure. Better nutrition can address yield gaps yet does not guarantee immunity to water deficits; peat-water management is especially important where land use is already established on peat. At the same time, simply reporting additional fertiliser after drought without soil assessment could worsen waste, costs or downstream pollution. Figure 2 presents the distinct short- and long-run channels and the operational data that would be required to validate them. The synthesis favours regional early warning, verified water conditions, protection against fire, continuity of harvest logistics and multi-year yield tracking over a single deterministic forecast for 2027 or 2028.

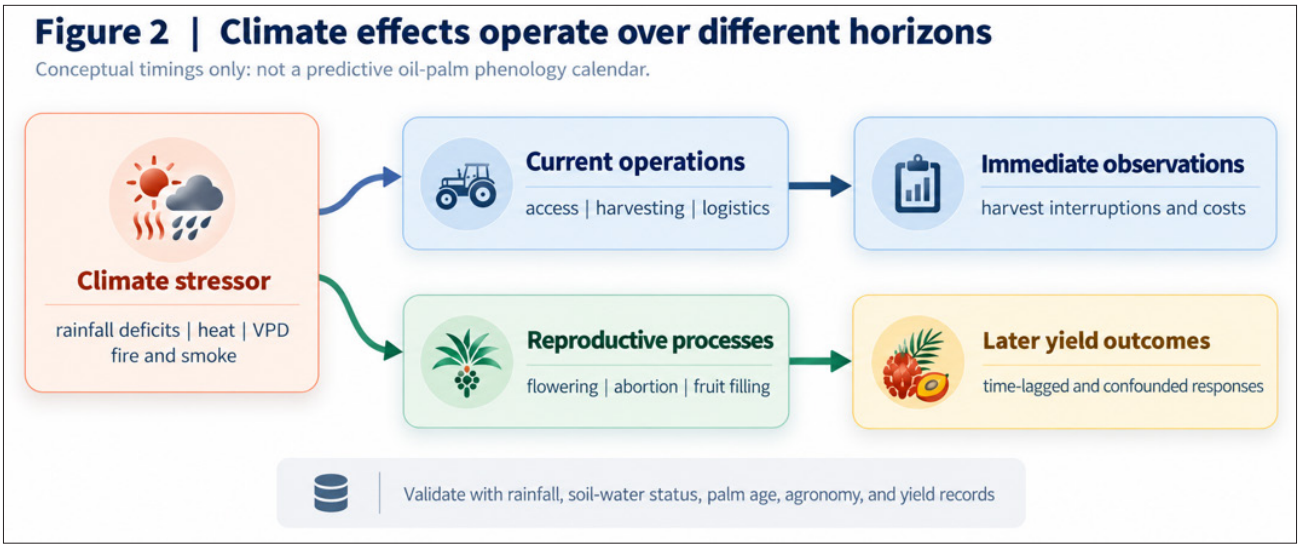


Figure 2: Immediate And Delayed Pathways from Climate Stress to Palm Output

Figure 2 distinguishes the immediate channels of labour access, fire and transport from lagged pathways associated with inflorescence and fruit development. The horizontal sequence is schematic and does not assign a universal number of months to each physiological stage, because the lag structure varies across conditions and studies. It also highlights the need for pre-event baselines: without data on palm age, soil water, rainfall, fertiliser application and harvest records, apparent climate effects can be confounded by management and

existing yield cycles. The proposed monitoring chain is therefore a research design aid rather than a reconstruction of actual losses during Q4 2026.

PSR is Necessary for Long-Run Capacity but Cannot Erase Short-Run Constraints

The fourth finding concerns the difference between theoretical productivity potential and the timing of additional marketable supply. The IPOSS outlook identifies the Oil Palm Replanting programme (Peremajaan Sawit Rakyat, PSR) as a critical strategic response when expanding planted area is neither environmentally desirable nor reliably feasible. Evidence supports this priority because ageing palms, insufficient inputs and management shortfalls create substantial smallholder performance gaps. Nevertheless, removing old trees initially reduces harvests while young palms establish, and the timing of future output depends on planting material quality, agronomy, the fraction of land replanted and survival rates. A successful PSR programme is thus a long-run capacity investment with near-term income and volume consequences, not a one-year supply switch.

A viable implementation sequence must address farm-level liquidity and institutions as well as biological yield. Farmers may have inadequate collateral, uncertain titles, weak cooperative support, limited access to verified seedlings and insufficient income alternatives during the immature phase. Studies on growers' willingness to replant and their exposure to financial risk demonstrate why subsidy or loan amounts alone do not explain uptake. Complementary measures include temporary livelihood support, reliable nurseries, agronomy extension, risk-sharing arrangements, timely administration and transparent monitoring of replanting blocks. High-quality management of mature existing stands should proceed in parallel with PSR, because near-term nutritional and harvesting improvements can contribute without waiting for new palms to bear [48].

Fiscal Instruments Have Joint Revenue, Incentive and Distribution Effects

The fifth finding is that export levies and export duties must be evaluated as an integrated system rather than as isolated tariff rates. In the IPOSS scenario, the export levy both reduces the calculated netback on eligible product shipments and supplies one source of programme finance. Export duties follow their own tariff classification rules and regulatory objectives. Neither the formal rate nor the reference price automatically determines the price received by a smallholder because domestic refining capacity, transport constraints, market structure, product composition and trader margins intervene. Financial-market studies support the idea that benchmarks and futures can aid price discovery, but volatile or illiquid market conditions may restrict the reliability of price signals. Domestic price pass-through and tax incidence should therefore be tested using transaction data rather than inferred from the movement of an international benchmark.

This creates a financing paradox under mandate expansion. A larger domestic biodiesel requirement can increase eligible subsidy volumes when the reference-price differential is positive, while displaced export shipments may erode part of the levy base. Higher palm prices can partly raise per-unit collections but may also increase feedstock costs, so the net effect is contingent. The IPOSS report's simplified breakeven illustration uses assumptions about total biodiesel volume, average levy collection and funding for other BPDP programmes. Its analysis offers a useful warning, not a forecast of actual liquidity: the fiscal balance should be constructed from product-specific levy revenues, eligible volumes, payment delays, reserve rules and stress-tested prices. Studies of Indonesia's biodiesel fiscal performance point towards flexible support, funding diversification and transparent rules rather than assuming that larger mandates automatically fund themselves.

Distributional Effects Depend on Smallholder Position and Value-Chain Power

The sixth finding concerns who gains when the palm sector creates additional domestic value. Government accounts may record avoided diesel imports; companies may earn processing margins; exporters face changed netbacks; and workers and smallholders may encounter different prices or employment opportunities. These gains and costs cannot simply be added without preventing double counting and addressing the distribution of taxes or subsidies. Survey and certification research in Indonesia shows that smallholder outcomes differ by organisational affiliation, local infrastructure, farm productivity and access to buyers. Even a policy with positive aggregate value can disadvantage households that are low yielding, highly indebted or outside formal support networks.

The most convincing welfare analysis therefore monitors producer prices net of fees, harvested volumes, production costs, debt service, price volatility and household living standards, alongside the ownership of processing and logistics benefits. The financial and administrative burden of certification provides a cautionary analogy: a farmer may gain credentials but see limited premium or higher compliance costs. Qualitative research on farmer perceptions of agroforestry similarly identifies a gap between environmental desirability and perceived personal income risk. Policy design that treats growers as passive feedstock suppliers may therefore miss incentives that determine whether national productivity and sustainability programmes succeed. Cooperative facilitation, transparent purchasing terms and independently observable inclusion indicators are more reliable than counts of farmers formally enrolled.

Export Competitiveness Increasingly Depends on Proof, Not Only Price

The seventh finding is that international competitiveness is partly institutional. The IPOSS document treats EUDR readiness, commodity-market institutions and land-tenure policy as strategic determinants of future market access. Peer-reviewed research confirms that traceability and zero-deforestation commitments can affect sourcing channels, but also finds uneven implementation and low penetration of sustainability information among independent growers. In a study of Indonesian oil-palm value chains, Chandra et al. identified substantial gaps between formal zero-deforestation policies and training or benefits reaching producer households. This suggests that a fully traceable export route requires more than declarations by downstream traders: mills, collectors and growers need consistent identification, records and procedures that recognise practical constraints [49].

Land rights can be a binding constraint on both compliance and investment. When farm boundaries or lawful access are disputed, geolocation alone does not resolve title validity, community consent or overlapping claims. Indonesian land-conflict research shows that the labels and narratives through which claims are framed can shape the availability of remedies, while palm-expansion studies emphasise insecurity in tenure conditions. Global work on EUDR implementation highlights that companies must negotiate standards, verification responsibilities and supplier relations under imperfect information. For producers, viable compliance requires legal clarity, proportionate documentation support, confidential

data governance, avenues for dispute and a fair approach to farm rehabilitation. Expanding certification without these fundamentals may create paper compliance without substantive inclusion (Afrizal et al., 2024; Berenschot et al., 2024; Grabs, 2025; Solar et al., 2025; Muradian et al., 2025).

No Single Policy Lever Independently Resolves the Trilemma

The eighth result synthesises the preceding themes: none of a higher blend, an export cap, higher export duties, accelerated PSR, a CPO price forecast or a new traceability platform can be evaluated as a stand-alone solution. Every measure interacts with timing, physical quantity, incentives, distribution and environmental boundaries. Reducing exports may preserve feedstock temporarily while reducing netback or levy proceeds; planting more productive palms will not solve this quarter's supply tightness; increased certification can improve documentation but will not automatically make smallholder production more profitable. Industry transformation studies further show that governance reforms require political coalitions and workable implementation pathways, while economic models warn that nominal policy targets without behavioural and supply constraints may produce optimistic counterfactuals.

Table 1 consolidates the eight themes into claims, evidentiary limits and implications. The principal pattern is conditionality: expected outcomes depend on clear denominators, compatible incentives and data capable of distinguishing mechanisms. From a QLR perspective, the result is not a ranking of the eight themes but a case for integrated measurement: energy substitution, export revenues, ecological conditions, production quality, fiscal balances and grower livelihoods belong in a shared policy dashboard. Without that dashboard, even a successful component programme may cause hidden costs elsewhere, especially during climate or market shocks.

Table 1: Evidence Map for Eight Interacting Palm-Oil Policy Themes

Theme	Supported mechanism	Principal limitation	Required verification
Physical balance	Stock and end-use mismatch	Product equivalents and adjustments	Reconciled primary-oil ledger
Biodiesel	Energy-import substitution and trade costs	Eligible fuel volume differs from headline blend	Reference-price and feedstock series
Climate	Immediate disruption and lagged crop response	Confounding by age and management	Multi-year site and yield records
PSR	Future yield growth with current replanting trough	Financing and land status vary	Cohort-level area, costs and survival
Prices and fiscal instruments	Netback, levies, support requirements	Tax incidence and product mixes differ	Transactional prices and BPDP accounts
Welfare	Distributional gains and risks	Farm types and buyer access differ	Farm income, debt and prices
Market governance	Traceability and market access	Documentation costs and tenure disputes	Plot-to-shipment records and remedies
Coordination	Joint policy trade-offs	Nonlinear and time-dependent effects	Scenario thresholds and review process

Table 1 is an evidence map rather than a quantitative meta-analysis. Its final column identifies the minimum verification required to move from literature-supported possibility to defensible national policy choice. The table separates direct evidence from scenario propositions and shows why several attractive interventions may need pilot evaluations, administrative data linkage or sensitivity analysis before their long-term effects can be asserted. This approach prevents the accumulated uncertainty from disappearing simply because each individual component study is credible.

Discussion and Analysis

An Integrated Three-Balance Analytical Architecture

The primary analytical recommendation is to replace parallel sectoral scorecards with three interacting balances. The first is a physical balance that records primary-oil-equivalent supply, end uses and usable inventories. The second is a fiscal and market balance comparing energy-substitution benefits, export opportunity values, product-specific levies and actual or contingent support obligations. The third is a resilience and legitimacy balance assessing where land, water, farmers, labour and public ecosystems bear risk. Each balance can be individually positive while the overall intervention remains unacceptable: a physically feasible fuel programme may exhaust a funding reserve, an apparently profitable export pathway may rely on recent forest conversion, or a productive replanting scheme may leave participating households without transitional income. International commodity assessments and agricultural trade-off frameworks reinforce the need for such multidimensional interpretation.

For physical accounting, the conceptual identity is presented in Equation 1. All terms are to be measured in the same primary-oil-equivalent basis, and separate subaccounts are required where CPO and PKO serve fundamentally different uses. The adjustment term makes the accounting transparent instead of silently assigning all mismatch to stocks; it can encompass measured losses, statistical discrepancies or explicitly documented conversion adjustments. Because the identity subtracts A_t, a positive A_t represents a net deduction from available primary-oil equivalents and a negative A_t represents a net addition; its components should be itemised rather than treated as freely adjustable. On this foundation, an analyst can report both a strict commodity balance and a broader product-flow reconciliation without claiming that physically non-equivalent tonnes are interchangeable. Neither the identity nor a plausible stock reconstruction proves causality, but each provides a necessary consistency check before evaluating alternative policy allocations.

$$S_t = S_{t-1} + P_t + M_t - D_t - X_t - A_t$$

Equation 1: Consistent-Period Primary-Oil Inventory Identity
Equation 1 defines S_t and S_{t-1} as closing and opening usable stocks, P_t as production, M_t as imports, D_t as domestic use, X_t as exports and A_t as net deductions or statistical adjustments during period t. Quantities must be expressed in tonnes of a declared equivalent primary oil, with a documented adjustment ledger and separate subaccounts when CPO and PKO are not materially substitutable. It is an accounting representation, not a predictive production equation. Each CPO or PKO stream must first be classified and converted by stated yields where cross-product equivalence is genuinely required. A separate documented subaccount should report biodiesel kilolitres and implied feedstock requirements, making it impossible to mistake the fuel volume for the same volume or mass of crude oil.

The fiscal linkage can be expressed as a second, intentionally simple equation. The programme's provisional financing margin equals verified earmarked receipts and authorised financing transfers minus the actual eligible blending support and other committed expenditure; a positive accounting margin does not necessarily imply short-run liquidity if disbursements and collection dates differ. For stress testing, biodiesel support itself can be approximated from the positive reference-price gap times the volume legally eligible for that support, with conversion and payment terms made explicit. The IPOSS scenario illustrates this sensitivity but cannot supply an audited final balance. Fitrady et al. find that fiscal vulnerability rises in combinations where levy receipts are volatile and subsidy costs are high, providing a basis for rules-based reserve thresholds rather than a fixed annual extrapolation.

$$F_t = L_t + T_t - B_t - O_t$$

$$B_t = \max(0,\ p_{bio,t} - p_{diesel,t})\, V_{eligible,t}$$

Equation 2: Illustrative Programme Financing Balance and Eligible Support
Equation 2 defines F_t as the net programme-financing margin, L_t as earmarked levy receipts, T_t as authorised transfers, B_t as legally eligible blending support and O_t as other committed expenditures over the same period. In the illustrative support expression, the biodiesel and petroleum-diesel reference prices are expressed in currency per unit of fuel, and the eligible volume is expressed in the corresponding fuel unit. If prices are quoted per litre but physical fuel is recorded in kilolitres, the volume must be converted before multiplication; this expression must not be used to infer audited fund balances from policy targets. Expenditure obligations should include programmes other than biodiesel where financed from the same fund, and export receipts should be estimated by product-level realised collection rather than an unweighted national average. The equation is valuable precisely because it can be audited against fund accounts once actual data become available.

Comparing Five Conditional Policy Scenarios
A scenario comparison helps identify trade-offs without pretending that the present literature supplies precise probabilities or elasticities for 2027. The reference case assumes the IPOSS general allocation trajectory but no unobserved productivity acceleration; it is a comparator rather than a prediction that all the IPOSS figures will materialise. Scenario A maintains a higher biodiesel requirement despite flat feedstock supply. Scenario B combines higher biodiesel requirements with earlier agronomic improvements and a credible medium-term replanting pipeline. Scenario C introduces adverse climate exposure and disrupted operational access. Scenario D allows rules-based biodiesel support and reserve flexibility in response to market and funding conditions. Scenario E adds stronger traceability with differentiated farmer inclusion. Each scenario must be evaluated under the same physical and financial definitions.

Table 2: Illustrative Conditional Policy Scenarios; Not Quantitative Forecasts

Scenario	Policy assumption	Main risk / possible result	Decision check
Reference	IPOSS directional baseline	Defines comparator; not realised 2026 totals	Validate series and unit equivalence
A: rigid B50	Demand rises; yield unchanged	Potential stock drawdown or export adjustment	Feedstock and finance stress trigger
B: B50 + yield strategy	Higher medium-term potential	PSR transition losses; implementation delays	Agronomy controls and verified cohort yields
C: climate shock	Lower or disrupted supply	Greater stock and price pressure	Regional exposure and reserve check
D: flexible financing	Support adjusts to fiscal conditions	May alter realised blend coverage	Public benefit, reserve and fuel-quality rules
E: inclusive traceability	Greater market credibility	Fixed costs or supplier exclusion risk	Independent-smallholder inclusion criteria

Table 2 deliberately reports directional pressures rather than numbers. Under an unchanged production baseline, higher energy diversion increases the potential for inventory drawdown or export adjustment if other uses are protected. Under an agronomic improvement scenario, this pressure can soften, but PSR cannot be expected to deliver a full yield response within the same year. Climate stress worsens uncertainty at a time when stock protection may be more valuable, while flexible fiscal support could reduce payment risk without necessarily meeting the originally announced blend in every possible condition. Inclusive traceability can defend market access but needs upfront expenditure. These outcomes are contingent on assumed demand elasticity, administrative feasibility and exchange-rate or fuel-price movements; their signs should be validated in a calibrated sector model before operational thresholds are adopted.

Figure 3 integrates these trade-offs as a feedback system rather than a one-way production diagram. It shows a scenario shock propagating through feedstock supply, the domestic energy requirement, export availability, levy receipts and household outcomes, with governance and environmental constraints acting as safeguards. The arrows are directional hypotheses, not estimated elasticities, and the circular links make visible the possibility that changing one policy instrument will influence the fiscal capacity to maintain another. A useful follow-up would be to test the framework under alternative oil-price, crop-yield and fuel-demand assumptions while reporting the distribution of outcomes between government, energy consumers, producers and processors.

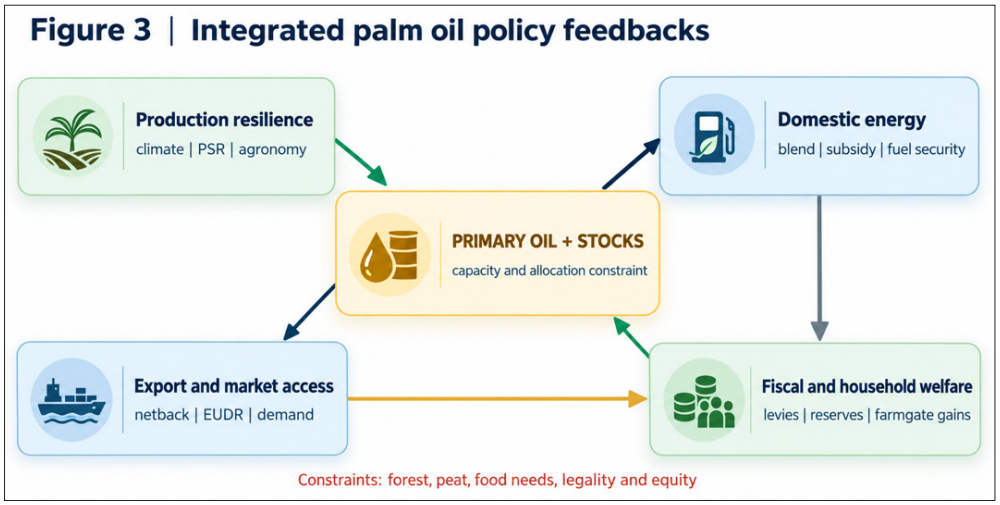


Figure 3: Interdependent Production, Biodiesel, Export and Financing Feedbacks

Figure 3 is best read from its centre outward: available primary oil and inventory buffers constrain feasible allocations; energy choices and export market performance then feedback through prices, fiscal transfers and producer income. Climate and forest safeguards remain constraints rather than tradable benefits to be overridden by favourable margins. The diagram therefore discourages the practice of declaring an energy policy sustainable solely because domestic fuel use or palm processing value added has increased.

Prioritising Capacity Without Transferring Environmental Costs

The evidence indicates three distinct resilience investments. First, existing mature smallholdings can be targeted for proven improvements in crop nutrition, harvest recovery and management, with baseline yield measurements and appropriately controlled trials. Second, PSR needs a credible long-term pipeline based on verified planting materials, clear titles, reliable finance, transitional household income and farmer organisations. Third, ecological resilience requires protection of remaining forests, peat-water management where applicable, and landscape arrangements that avoid misleading claims of carbon or biodiversity equivalence. These investments are complements but operate on different timescales and cannot substitute for one another. Some agronomic gains can be relatively prompt; replanting creates a yield trough; and ecological damage from new conversion cannot be assumed reversible through higher yields elsewhere.

Funding choices should follow this timing. When the fiscal margin from biodiesel support is temporarily positive, allocating the entire perceived surplus to new commitments would expose other programmes to future price-gap reversals. The IPOSS outlook itself notes the case for strengthening buffers and safeguarding replanting support. A preferable institutional design sets transparent multi-year funding envelopes for PSR, extension, environmental monitoring and eligible energy support, with reserve adequacy and stress triggers published separately. This approach recognises that a levy-funded programme may face a revenue contraction when domestic processing expands or export prices fluctuate. The optimal reserve level cannot be established by a QLR, but the requirement for explicit rules follows directly from the documented interaction of price, levy and mandate mechanisms.

Agroecological gains warrant a separate warning against simplistic claims. Studies show that tree islands, habitat set-asides and managed understory can support ecological functioning under certain oil-palm conditions; they do not establish that any diversified plantation offsets the loss of forest, nor that the intervention provides unlimited emissions reductions. Indonesian smallholder work on nature-based management documents heterogeneous yield outcomes, underscoring the need to avoid asserting that ecological improvements always pay for themselves through higher production. Where public biodiversity benefits exceed farm-level private returns, direct incentives, shared landscape financing or conservation contracts may be more coherent than demanding that growers absorb the full cost. Such mechanisms must also avoid rewarding expansion into previously undisturbed habitats [50,51].

Strengthening Trade Governance, Legal Certainty and Smallholder Inclusion

The EUDR-related and broader zero-deforestation compliance agenda creates a reason to invest in supply-chain data that also strengthens domestic administration. A robust system would connect plot registration, geolocation, lawful-use documentation, transaction records, mill intake and shipment-level verification without assuming every producer has equal digital capacity or secure title. It should specify who verifies declarations, resolves conflicts, funds remedial actions and protects commercially sensitive or personal information. Crucially, it must distinguish technical traceability from legal adjudication: the fact that a farm can be mapped does not establish that competing land claims have been resolved. Indonesian research into land rights, zero-deforestation commitments and certification illustrates the risk of excluding the weakest producers through a data-driven process whose costs are not shared fairly.

The market architecture also determines whether price information can improve bargaining power. A physical CPO exchange, a

derivatives market, and a public reference-price system serve different functions and need not generate liquidity merely because an institutional platform exists. Transparent settlement, sufficient participation, product specifications, credible delivery and reasonably low transaction costs are prerequisites to meaningful price discovery. Research on futures efficiency and commodity liquidity offers design lessons, but no inference that a particular proposed exchange will necessarily raise farmgate prices. Policies should distinguish an operationally functioning benchmark from price-discovery claims made before trading depth and actual settlement performance have been measured.

Distributional safeguards should therefore be evaluated alongside compliance. Indicators could include the proportion of independent growers receiving actionable technical support, the share of verified smallholder volumes accepted by compliant buyers, average documentation expense per hectare, days between delivery and payment, and the prevalence and resolution time of land-use complaints. For certification and jurisdictional schemes, comparative evidence shows that capacity building and local political legitimacy can matter as much as formal standards. The policy objective should be effective, verifiable and equitable participation, not simply maximal counts of polygons entered into a database. Implementation experiments should compare different financing and service-delivery models so that costly rules do not become an unintended barrier to legal smallholder livelihoods.

The evidence also cautions against assuming that an area-level conservation claim follows automatically from registration or yield improvements. Historical satellite mapping documents that the nature of forest conversion has varied among Indonesian palm-oil production regimes; future claims must therefore be tested against geographically explicit land-cover outcomes and credible baselines.

Governance Architecture, Monitoring and Research Priorities

The five-gate roadmap shown in Figure 4 provides a staged implementation logic: diagnose the balance and risk baseline; verify the physical and fiscal accounts; test policy packages under adverse conditions; pilot and independently evaluate delivery arrangements; and scale only approaches meeting predetermined thresholds. Each gate should permit a stop, revision or alternative option rather than assuming every recommendation must be implemented in the same form nationally. The institutional responsibilities and advancement criteria are specified in Table 3 so that each stage has evidence requirements rather than a symbolic approval step. Periodic dashboards should report physical allocation and inventories in equivalent units, realised biodiesel volumes, levy collections, payments, farm yields, PSR stage distribution, climate stress, export value and traceability coverage. Combined monitoring must be disaggregated by geography and producer group to avoid concealing regional vulnerability under favourable national averages.

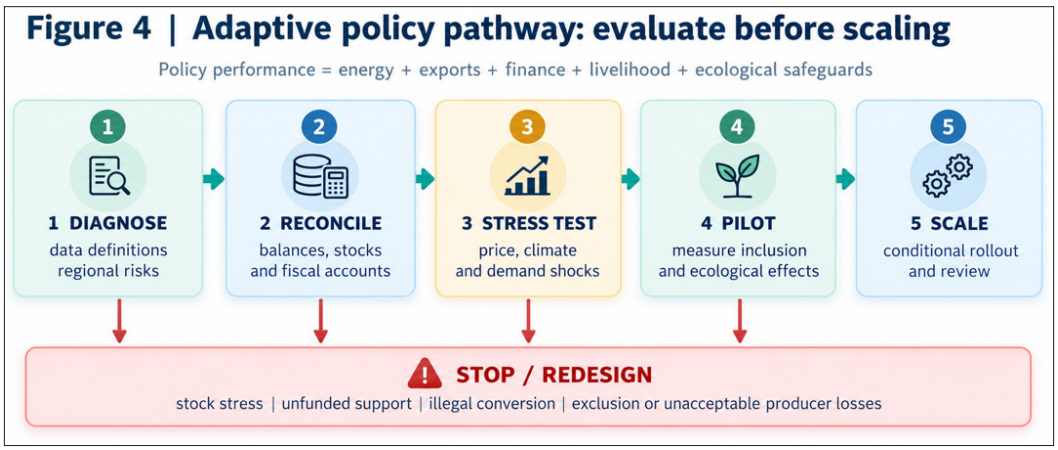


Figure 4: Five-Gate Adaptive Policy Implementation Roadmap with Redesign Triggers

Figure 4 illustrates the decision process and places stopping rules before the scale-up stage. A documented stock adequacy breach, a persistent fund financing gap, evidence of illegal habitat conversion, or exclusion of a vulnerable producer group should initiate investigation and potential redesign. Threshold values are intentionally not invented: they should be set through public consultation and quantitative analysis of operational data. The usefulness of the roadmap lies in making policy reversibility, accountability and evidence requirements explicit before commitments accumulate.

Table 3: Monitoring Responsibilities and Decisions at Five Adaptive Governance Gates

Gate	Lead institutions	Monitoring evidence	Rule for progression
Diagnose	Oil-palm and climate agencies	Yield, usable stocks, regional exposure	Publish definitions and baselines
Reconcile	Energy, trade and fiscal agencies	Oil equivalents, eligible biodiesel, levies	Explain residuals and conversion factors
Stress test	Joint technical secretariat	High/low price, climate and export demand	Declare reserve and deficit thresholds
Pilot and evaluate	Farm groups, mills and regulators	Profit, yield, ecological and equity indicators	Third-party assessment and complaints
Scale or revise	Policy steering group	Threshold compliance and distribution	Time-bound public review and reversibility

Table 3 translates the five gates into monitoring responsibilities and auditable evidence. Agricultural agencies and farmer organisations need comparable field records; energy administrators require verified blend and fuel-use data; fiscal authorities need a transparent levy and incentive ledger; environmental authorities need credible land-use and peat monitoring; and market institutions need shipment-level traceability and accessible dispute procedures. A shared dashboard does not mean that all data must be held in one unrestricted database: purpose limitation, interoperability and independent checks can preserve both accountability and the confidentiality of farm and commercial information.

Research should now move beyond isolated simulation exercises. First, a reconciled national commodity-flow account needs publicly documented transformation coefficients and monthly inventory checks across CPO, PKO, refining and biofuel streams. Second, causal or carefully controlled quasi-experimental evaluations should compare the effects of different management and PSR support models on yield, profit, debt and land-use outcomes. Third, biodiesel fiscal analyses should link fuel prices, eligibility, real disbursements and levy receipts under multiple stress scenarios, rather than assuming constant price gaps. Fourth, traceability studies should assess actual exclusion, training uptake, cost allocation and land-tenure solutions for independent farmers. Fifth, climate-response studies should combine long-run physiological data with production, logistics and satellite exposure so that one episode of weather is not simplistically mapped onto next year's harvest.

A final limitation is the QLR design itself. The included literature is heterogeneous and selected for conceptual relevance, which supports interpretation but not a precise combined average policy effect. Some supporting studies concern other agricultural commodities or external regions; others employ observational designs that cannot distinguish all confounding variables. The IPOSS scenario is useful because it connects many operational domains, but without access to full underlying model code, harmonised raw trade series and administrative audit records, its projections should not be presented as externally replicated findings. The proposed integration framework is thus falsifiable: if new evidence shows different conversion yields, finance flows, climate exposures or market responses, the recommended choice may change. Such openness is a strength of adaptive policy analysis rather than a weakness to be hidden [52-57].

Conclusion and Recommendations

Indonesia's palm-oil policy dilemma is not reducible to a choice between domestic energy independence and export competitiveness. Available evidence instead points to an interacting system in which a biodiesel mandate changes the composition of demand, while crop biology, weather exposure and uneven agronomic capacity shape the timing of additional supply. Prices, export levies and fiscal incentives transmit these changes across the value chain, and evolving deforestation-related due diligence and land-use governance influence which producers can access valuable markets. The IPOSS fourth-quarter 2026 outlook offers a useful scenario of these pressures, but its forecasts and assumptions must not be mistaken for verified year-end national outcomes.

The synthesis supports a conditional policy strategy. Physical accounting should first be harmonised across product streams and time periods; national biodiesel support should then be evaluated with transparent fiscal and inventory safeguards. Productivity-led supply enhancement should combine better current agronomy with a financially and socially viable PSR pipeline, without using projected yield gains to justify conversion of forests or peat. Export competitiveness should be defended through credible price formation, proportionate traceability and meaningful inclusion of independent growers. No single intervention can guarantee simultaneously higher energy substitution, export revenue, fiscal solvency, farm welfare and biodiversity, so trade-offs must be published rather than disguised.

Policy makers should establish jointly monitored thresholds for usable inventories, programme financing coverage, farm-level income risk and environmental compliance, then test proposed interventions under high and low price, adverse climate and different export-demand conditions. Comparative field evaluations, auditable public-finance records and transparent governance pilots are essential to determine which combinations can responsibly scale. The contribution of this review is an integrated decision architecture for interpreting competing objectives, not a claim that a single numerical optimal blending mandate or 2027 production outcome has already been established.

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