INDEPENDENT SYSTEMS RISK ANALYSIS

From Hormuz to Hunger:

The Compound Cascade That Institutional Models Miss

By Jonathan Kelly

Independent Systems Risk Analyst | americasoilwatch.com | eurooilwatch.com | ukoilwatch.com

Why the gap between official projections and systems analysis is itself the most important finding

Policy Brief | Version 3.3 | 10 May 2026

18 primary sources | 30-section integrated model | 4 scenarios with sensitivity analysis

Sources: GRFC 2026, World Bank CMO April 2026, UNCTAD, FAO, WFP, Fertilizers Europe

Executive Summary

The Methodology Gap

The WFP projects +45 million people into acute food insecurity. The FAO warns of a potential "global agrifood catastrophe." The GRFC 2026 documents 266 million people in IPC Phase 3+ acute food insecurity across 47 countries. WFP separately identifies a pre-conflict baseline of 318 million food-insecure people across 53 countries — the population on which Hormuz-driven price shocks act most directly.

These institutions are working with accurate data and credible models. This analysis uses **the same data** and arrives at dramatically different conclusions — not because it disputes the institutional inputs, but because it models something they do not: **the compound interactions between nine causal chains** that amplify a fertilizer disruption into a multi-continental famine. Institutional models are linear and additive. Reality is interactive and multiplicative. The gap between the two is this report's central finding.

What the Model Shows

The analysis builds upward from established facts in three layers:

Layer	Estimated excess deaths	What drives it	Confidence
Layer 1: Damage from disruption to date	20–35 million	2026 planting cycles missed; supply chain lags; acute malnutrition in progress	**HIGH**
Layer 2: Structural amplification	+60–155 million	Doom loops, export bans, market fragmentation, logistics ceiling, disease	**MEDIUM**
Layer 3: Conditional cascades	+85–155 million	El Niño, full autarkic collapse, prolonged closure >12 months	**CONDITIONAL**

Layer 1 is not in dispute — it reflects damage documented in current FAO/WFP reporting. **Layer 2 is where the methodology gap lives** — these are the compound interactions that institutional models do not capture. **Layer 3 is conditional** on binary variables (El Niño, India export decisions, blockade duration) that the model cannot predict but can quantify.

The probability-weighted central estimate across all scenarios is **169–334 million excess deaths**. The range is wide because of genuine uncertainty about Layer 3 variables. But even the low end of this range is about 4× higher than institutional projections because of Layer 2 — the compound cascades.

This is an expected-value calculation across all scenarios, not a prediction that this specific number will occur. The single most likely scenario is the base case (95–200 million at 30–40% probability). The expected-value framing is standard in risk assessment because it captures both likelihood and magnitude.

How Deaths Are Calculated

The mortality estimate is built transparently from regional crude mortality rate (CMR) data calibrated against historical famine observations. The table below shows the conversion from food-insecure population to estimated excess deaths by region:

Region	Population at risk (M)	Crisis CMR range	Est. excess deaths (M)	Confid-ence
South Asia	280–420	0.8–1.5 / 10,000/ day	15–45	**MEDIUM**
Sub-Saharan Africa (non-conflict)	150–220	1.0–2.0 / 10,000/ day	10–30	**MEDIUM**
Conflict/access-denied zones	80–120	2.0–6.0 / 10,000/ day	15–50	**HIGH**
MENA food importers	60–100	0.5–1.2 / 10,000/ day	3–12	**MEDIUM**
Latin America/Caribbean	30–50	0.6–1.0 / 10,000/ day	1–5	**LOW**
Direct subtotal	**600–910**	—	**44–142**	—

The gap between the direct subtotal (44–142 million) and the central estimate (169–334 million) is accounted for by compound chain interactions — primarily disease multiplication and autarkic market fragmentation — which increase both the population at risk and the crisis CMR. Each regional CMR is calibrated against observed rates in comparable historical famines (Bengal 1943, North Korea 1994–98, Somalia 2011). The full methodology, including CMR source calibration, is in the Technical Report.

Why Institutional Models Undercount

What institutions model	What they miss	Historical consequence of missing it
Direct food price impact on food access	Sovereign debt doom loop (countries can't afford food at any price)	Bengal 1943: food existed but entitlements collapsed → 2–3M dead
Short-term supply disruption	Multi-cycle yield collapse from consecutive fertilizer absence	North Korea 1994–98: one bad year became four → 0.6–3.5M dead
Country-level food balance sheets	Autarkic market fragmentation (export bans destroy the market itself)	Late Victorian Holocausts: market integration transmitted famine → 30–60M dead
Nutritional needs of affected population	Disease multiplication as function of access denial	Every historical famine: disease killed 2–3× more than starvation
Individual risk factors assessed separately	Compound interactions where chains trigger and amplify each other	Every major famine: mortality exceeded projections by 3–10×

> **THE HISTORICAL PATTERN**
>
> In every major famine in the historical record, contemporaneous institutional projections underestimated final mortality by 3–10×. The systematic cause: second-order effects (disease, market collapse, displacement, policy failure) were not modelled. The 2026 crisis has more compounding factors operating simultaneously than any single historical precedent.
>
> **The question for the reader is not: "Is this estimate higher than official projections?"**
>
> **The question is: "Has history ever shown that official projections adequately capture compound famine dynamics?"**
>
> The answer, across every case study in the calibration set, is no.

---

1. The Crisis: What Has Happened

On 28 February 2026, US and Israeli military strikes on Iranian nuclear and military facilities triggered Iran's closure of the Strait of Hormuz. Daily vessel transits collapsed from 141 to 4 — a **97% reduction** (UNCTAD, April 2026). Two months later, the strait remains effectively closed under a "fragile" ceasefire (World Bank CMO, April 2026).

The Strait of Hormuz carries ~30% of internationally traded fertilizer, including 67% of Gulf urea exports (~16M tonnes). **No strategic fertilizer reserves exist anywhere in the world** (FAO, Middle East Situation Report, 2026). Unlike oil — where the IEA coordinated release of 400 million barrels from strategic reserves — there is no equivalent mechanism for the agricultural input that determines whether crops grow.

The fertilizer-yield relationship is **non-linear**: a 10% fertilizer reduction produces approximately a 25% harvest loss. This ~2.5× average multiplier varies by crop: 15–20% loss for well-fertilized commercial maize, 30–50% for subsistence millet and sorghum in the Sahel where baseline application is lowest. The populations at highest mortality risk face the steepest yield-sensitivity curves. Even at a conservative 1.5× multiplier — below published agronomic estimates — the model still produces 110–217M excess deaths because Layers 2 and 3 operate through mechanisms independent of the yield relationship.

As of April 2026, global nitrogen production is down ~20% with prices up ~70% (World Bank CMO). Country-level dependencies on Gulf fertilizer are severe: Sudan 54%, Sri Lanka 36%, Somalia 30%, India 20% of nitrogen imports (UNCTAD; FAO).

---

2. Nine Causal Chains

The model identifies nine mechanisms through which the Hormuz blockade transmits into mass starvation. Each is individually sourced. The critical finding is that they **interact** — each triggers or amplifies others — producing compound effects that no single-factor analysis captures.

Chain 1: Yield Collapse (Direct) — *Confidence: HIGH*
Hormuz → fertilizer shortage → 10% input cut ≈ 25% yield loss → food deficit across South Asia, Sub-Saharan Africa, Latin America. Affects both 2026 and 2027 planting cycles.
Impact: 40–70M direct.

Chain 2: Shadow Famine Lock-in — *Confidence: HIGH*
Even if Hormuz reopens tomorrow, damage is locked in: fertilizer not ordered, shipping contracts lapsed, insurance repriced. Five-stage supply-chain lag means 8–14 months from reopening to restored delivery.
Impact: 20–35M floor.

Chain 3: Sovereign Debt Doom Loop — *Confidence: MEDIUM*
Food importers borrow at crisis rates → debt crisis → currency collapse → food more expensive → deeper borrowing. Self-reinforcing. 40+ countries at risk simultaneously. Sri Lanka 2022 demonstrated the mechanism at country scale.
Impact: +15–40M.

Chain 4: Fertilizer Export Cascade — *Confidence: MEDIUM*
Producing countries restrict fertilizer exports to protect domestic supply (China did this in 2022 under less pressure). Each restriction tightens global supply further, triggering additional restrictions.
Impact: +10–25M.

Chain 5: El Niño Convergence — *Confidence: CONDITIONAL*
If El Niño develops (40–55% probability), it simultaneously reduces monsoon rainfall in South Asia, increases East African drought, and disrupts Latin American agriculture. Acts as a **coupling variable** connecting otherwise independent chains.
Impact: 1.3–1.8× multiplier.

Chain 6: Autarkic Market Fragmentation — *Confidence: CONDITIONAL*
Countries ban food exports (India banned rice in 2023 under less pressure). If India, Vietnam, Thailand, and others simultaneously ban, the global food market ceases to function. India's decision is the single largest binary variable.
Impact: +20–60M.

Chain 7: Humanitarian Access Denial — *Confidence: HIGH*
Highest-risk populations are in conflict zones: Sudan (70%+ hospitals destroyed), Sahel (NGOs expelled), Somalia (Al-Shabaab), Myanmar, DRC. 60–120M people are in zones where aid cannot reach regardless of funding.
Impact: Prevents mitigation.

Chain 8: Logistics Ceiling — *Confidence: HIGH*
WFP can effectively assist ~110M people (its own 2026 target). The crisis population exceeds 300M. The gap is a hard physical constraint: port throughput, inland transport, warehouse capacity.
Impact: Caps response.

Chain 9: Disease Multiplication — *Confidence: HIGH*
Famine-associated disease historically kills 2–3× more than direct starvation. Split multiplier: 1.3–1.8× in accessible zones, 2.5–4.0× in access-denied zones, 5–10×+ if H5N1 crosses over (3–8% probability).
Impact: 1.8–2.5× blended.

> **HOW CHAINS INTERACT — WHY COMPOUND > LINEAR**
>
> The doom loop (Chain 3) makes export bans (Chain 6) more likely — desperate countries hoard. Export bans make the doom loop worse — less grain at any price. Disease multiplication (Chain 9) is a function of access denial (Chain 7), not a fixed constant. El Niño (Chain 5) couples India's harvest to its export policy to autarkic fragmentation to the logistics ceiling. These are not additive risks. They are **feedback loops**. The compound effect is why this model produces estimates 3–5× higher than the sum of institutional single-factor assessments.

---

3. Scenarios and Sensitivity

Scenarios

Scenario	Excess deaths	Probabil-ity	Key assumptions
Best case	32–55M	6–10%	El Niño absent; Hormuz reopens by August; G20 emergency coordination
Combined positive	45–90M	10–15%	El Niño downgraded; partial reopening (30–50%) holds
Base case	95–200M	30–40%	Hormuz closed 6–12 months; partial El Niño; limited coordination
Worst case	300–650M	15–25%	Full closure 18+ months; strong El Niño; autarkic cascade
Catastrophic	650M+	3–8%	All worst-case conditions plus H5N1 pandemic crossover

> *Central estimate uses midpoint probabilities renormalized to sum to 100% (Best 10% / Combined positive 15% / Base 43% / Worst 25% / Catastrophic 7%); this assumes the named scenarios exhaust the outcome space.*

What Variables Matter Most

Variable	Impact on central estimate	Policy controllability
Hormuz blockade duration	±40–60%	**HIGH** — ceasefire/settlement negotiations
El Niño development	±20–35%	**NONE** — climate variable
India export ban decision	±15–25%	**MEDIUM** — diplomacy
Humanitarian access (Sahel/Sudan)	±10–20%	**MEDIUM** — negotiation
G20 emergency coordination	±10–15%	**HIGH** — political will
China grain reserve release	±3–5%	**LOW** — internal CCP decision

The August 2026 threshold: The model identifies a non-linear transition at roughly 5–6 months. Below this, the crisis damages one crop cycle (painful but contained). Above it, consecutive cycles compound and the damage becomes self-sustaining. Every week of inaction past this threshold narrows the policy window.

---

4. Anticipated Objections and Responses

Each objection is stated in its strongest form.

“The estimate is much higher than official projections — it must be too aggressive.”

The estimate is higher because it models compound interactions that official projections do not. WFP projects +45M into food *insecurity* (hunger, not death), using a model that captures first-order price effects. This analysis models nine interacting chains including sovereign debt doom loops, market fragmentation, disease multiplication, and access denial — none of which appear in WFP’s methodology. The gap reflects a difference in **model structure**, not in **input data** or **subjective pessimism**.

“Modern systems are more resilient than historical analogs.”

Modern systems have more *capacity* but also more *fragility*. The global food system’s efficiency comes from interconnection, just-in-time logistics, and concentrated production — exactly the features that propagate systemic shocks faster. The IEA released 400 million barrels of strategic oil reserves and oil is still at elevated prices. There is no equivalent mechanism for fertilizer. Early warning systems exist, but there has been no policy response commensurate with the threat in the two months since the blockade began.

“Farmers will adapt — efficiency, substitution, crop switching.”

Nitrogen is non-substitutable for cereal protein synthesis. Marginal efficiency gains from precision agriculture are on the order of 5–10%, not enough to offset a 20%+ input reduction. Crop switching can worsen the economic dimension by reducing export revenue and accelerating the doom loop. Black markets redistribute existing supply; they do not create new nitrogen. The Ukraine-2022 comparison is inapplicable: that crisis disrupted *grain trade*; this crisis disrupts *fertilizer supply*. The relevant analog is North Korea after Soviet collapse, where fertilizer imports fell 50–80% and yields collapsed 30–60% despite adaptation.

“Food waste reduction and dietary shifts could offset the shortfall.”

Global food waste is ~30% of production, and shifting from grain-fed meat to direct grain consumption could, in theory, free calories. But:

- **Timescale:** Significant dietary shifts take years; the crisis window is 6–18 months.
- **Distribution:** Populations at highest mortality risk already waste very little and eat minimal meat; the waste-reduction opportunity exists in wealthy countries not at famine risk.
- **Nutrients:** Fertilizer-driven crop failures cause protein and micronutrient deficits not easily solved by redistributing existing food types.

The model already assumes some adaptation via a conservative fertilizer-yield multiplier.

“Global grain stocks are adequate — there’s enough food.”

There was enough food in British India during the Bengal Famine, in Ireland during the Great Famine, and globally during the Late Victorian famines. Amartya Sen showed that famines are driven by *entitlement failure* (who can command food), not just *aggregate availability*. The 2026 crisis is simultaneously:

- A fertilizer problem (future grain won’t exist as planned).
- A purchasing power problem (countries can’t afford existing grain).
- An access problem (grain can’t reach those in conflict zones).
- A market fragmentation problem (grain not available on functioning global markets).

Grain stocks address at best one of these.

“No official source projects 100M+ deaths.”

No official source *models the compound interactions that produce that number*. GRFC does not publish mortality projections. WFP publishes food insecurity projections, not death estimates. FAO publishes production and price forecasts, not mortality models. The absence of an official estimate reflects an **analytic gap**, not a refutation.

“The probability weighting assigns too much weight to worst cases.”

The base case (95–200M at 30–40% probability) is the modal outcome, not a tail. It assumes:

- Hormuz closed 6–12 months (already 2 months closed with only a “fragile” ceasefire).
- Partial El Niño (40–55% probability per NOAA).
- Limited international coordination (in line with recent track record).

The worst case requires sustained closure with strong El Niño and autarkic cascade — a combination that is unlikely but not remote. A 15–25% probability for further escalation in an ongoing conflict is, if anything, conservative.

---

5. Policy Recommendations

Each recommendation is mapped to specific model variables and quantified by estimated lives saved.

Tier 1: Existential Priority

1. **End the Hormuz blockade or achieve partial reopening.**
   Impact: ~40–60% reduction in central estimate (roughly 70–200M lives). Even 30–50% traffic restoration, sustained through October 2026, could reduce the estimate to ~93–234M. Every month of delay past August locks in additional deaths by crossing the multi-cycle threshold.

2. **Establish a G20 Emergency Fertilizer Facility.**
   Create a coordination mechanism analogous to the IEA's oil reserve system to pool non-Hormuz supplies, prevent export bans, and allocate by agronomic need.
   Impact: ~10–25M lives.

3. **Prevent India from banning grain exports.**
   India is the world's largest rice exporter. An export ban both increases domestic risk and removes a key source of affordable rice from world markets.
   Impact: ~15–25M lives.

Tier 2: High-Impact Interventions

1. **Fully fund WFP's $13 billion 2026 requirement.**
   Cost-effectiveness: ~$650–$1,300 per life saved at the margin. WFP's delivery capacity is the binding constraint in accessible zones.

2. **Negotiate humanitarian access to Sudan and the Sahel.**
   The disease multiplier is effectively a proxy for access. Marginal funds for access and security arrangements save more lives than marginal medical supplies, because supply exists but cannot be delivered.

3. **Emergency sovereign debt relief for food importers.**
   IMF/World Bank facilities, debt moratoria, and SDR allocations can break the debt–food doom loop.
   Impact: ~10–20M lives.

Tier 3: Structural Measures

1. **H5N1 pandemic preparedness surge.**
   With a 3–8% probability of crossover during the crisis window, even modest mitigation (surveillance, stockpiles, health-system prep) has a high expected value.

2. **Fast-track alternative fertilizer production.**
   Restart mothballed nitrogen plants, accelerate African phosphate development, and invest in biological nitrogen fixation and green ammonia.

6. The Damage Already Done

THE ACTIONABLE MARGIN IS SHRINKING DAILY

Damage from disruption to date:
20–35 million excess deaths derived from damage already incurred — disrupted planting cycles, 8–14 month supply-chain lags, and acute malnutrition already rising in IPC4+ populations. This is an estimate with uncertainty: it could be lower if adaptation exceeds historical precedent, or higher if the disease multiplier exceeds the model's blended 1.8–2.5× assumption.

Actionable policy margin:
~80–235 million lives that can still be saved through the interventions above.

Every week of delay narrows this margin.
August 2026 is the threshold past which the crisis transitions from one-cycle damage (contained) to multi-cycle compounding (self-sustaining). Action before August preserves the option of containment. Action after August is damage mitigation at dramatically reduced effectiveness.

7. Methodology and Limitations

Sources: 18 primary sources including FAO, WFP, UNCTAD, World Bank CMO April 2026, GRFC 2026, Fertilizers Europe, UNU, and nine historical famine case studies.

Calibration: Death-toll ranges are cross-validated against nine historical famines with comparable initial conditions (Bengal 1943, China 1959–62, Biafra, Ethiopia 1983–85, North Korea, Somalia 2011, Irish Famine, Late Victorian famines, Soviet Ukraine). Mortality as a percentage of vulnerable population (6–11%) is within the historical 5–12% range.

Cross-validation: Model outputs are checked against FAO MIRAGRODEP CGE model parameters and IFPRI food-policy simulations for structural consistency.

Methodology framework:
The compound cascade methodology is published separately: Kelly, J., *Compound Cascade Systems Modelling Framework: A Reusable Methodology for Building Probabilistic Risk Models of Systemic Crises*, SSRN, May 2026.

Sensitivity: Six major variables are tested independently with quantified impact ranges.

Explicit Limitations

The model may **overestimate** if:

- International coordination exceeds historical norms.
- Fertilizer efficiency innovations outperform the literature.
- Multiple positive developments (Hormuz reopening + no El Niño + strong coordination) coincide.
- Farmer adaptation in non-marginal soils proves unusually effective.

The model may **underestimate** if:

- The conflict escalates or spreads.
- Additional supply chains are disrupted.
- H5N1 pandemic crossover occurs.
- Policy decisions at key nodes are worse than the probability-weighted assumptions.

The model does **not** predict which scenario will occur. It quantifies the consequences of each and identifies which interventions most effectively shift probability mass from worse to better outcomes. The goal is not prophecy; it is to make the cost of inaction legible.

Sources

(As listed in the original brief; kept as a numbered bibliography.)

1. FAO, “Chief Economist warns of severe global food security risks from disruption to Strait of Hormuz,” April 2026.
2. FAO, Middle East Situation Report, 2026.
3. WFP, “WFP projects food insecurity could reach record levels,” April 2026.
4. WFP Global Outlook 2026.
5. UNCTAD, “Navigating Troubled Waters: Impact on Shipping and Trade of the Middle East Conflict,” April 2026.
6. World Bank, *Commodity Markets Outlook*, April 2026.
7. Global Report on Food Crises (GRFC) 2026.
8. CSIS, “Iran, Fertilizer, and Food Security,” 2026.
9. Carnegie, “Fertilizer isn’t getting through the Strait of Hormuz,” March 2026.
10. Fertilizers Europe, Supply Chain Impact Assessments, 2026.
11. UNU-INWEH, *Water Bankruptcy in the Global South*, 2025.
12. Yao et al., “Global Irrigation Constraint Analysis,” 2025.
13. Historical famine works (Dikötter, Conquest, Mukherjee, Kinealy, Davis, Sen, etc.).
14. USDA FAS, Grain and Feed reports, 2025–2026.
15. NOAA CPC, ENSO forecast updates, April 2026.
16. *The Lancet*, “Global burden of bacterial AMR 2025–2050.”
17. WHO EWARS surveillance and cholera stockpile reports, 2024–2026.
18. IPC technical manual and country analyses, 2025–2026.
19. Kelly, J., *Compound Cascade Systems Modelling Framework*, SSRN, May 2026.