Structural Analysis of the Complex Fertilizer and Food Crisis Driven by Middle East Geopolitical Risk, and Verification of Alternative Agricultural Models

1. Introduction: The Superficial Relief of the Ceasefire and the Hidden Structural Rupture

The two-week ceasefire agreed upon between the United States and Iran on April 7, 2026, provided a pathway for the resumption of navigation through the Strait of Hormuz, albeit under the condition of Iranian military administration. International markets reacted to this announcement with temporary relief, shedding the geopolitical risk premium. However, this market reaction severely underestimates the physical constraints inherent in modern global supply chains.

The essence of the problem lies in the fact that even if the "transportation bottleneck" of the strait is resolved, the "production bottleneck"—the facilities that generate the goods meant to pass through it—has been fatally destroyed. Specifically, the chemical fertilizer supply chain, which forms the foundation of global food security, operates in complete integration with the fossil fuel refining infrastructure of the Middle East. The 39-day conflict inflicted irreversible damage on the energy infrastructure along the Persian Gulf coast. As long as the manufacturing facilities are physically devastated, fertilizers will not flow into the market regardless of the shipping lanes opening. This report rigorously verifies the validity of the provided hypothesis document and comprehensively analyzes how this crisis will irreversibly transform the global agricultural structure from the perspectives of energy markets, heavy electrical infrastructure (gas turbines), soil agronomy, and natural farming.

2. The "Byproduct Trap": The Historical and Chemical Inseparability of Fertilizer Production and Fossil Fuel Processes

The production base for nitrogen and phosphate fertilizers—two of the three major fertilizer elements (nitrogen, phosphate, and potassium) supporting modern global agriculture—is entirely dependent on the "byproducts" or "derivative processes" of the oil and natural gas industries. Since Justus von Liebig's discovery of plant nutrition in the 19th century, agriculture departed from the natural material cycle and transformed into an industrialized system (monoculture) dependent on synthetic chemical fertilizers.[1] In particular, the combination of the Haber-Bosch process invented in the early 20th century and the expansion of chemical production capacity during World War II led to an explosive 800% increase in global nitrogen fertilizer usage between 1961 and 2019, driving the so-called "Green Revolution".[1]

2.1 Nitrogen Fertilizer and the Natural Gas Reforming Process

The production of ammonia, the raw material for the world's most widely used nitrogen fertilizer (urea), is an extremely energy-intensive process. Modern fertilizer plants extract hydrogen from natural gas (primarily methane) and synthesize ammonia (NH3) by reacting it with atmospheric nitrogen under an ultra-high temperature environment of approximately 600°C.[2] In this process, about 80% of the consumed natural gas is used as a chemical feedstock, while the remaining 20% is consumed as fuel for process heating and in-house power generation.[3] Furthermore, urea is manufactured by reacting this ammonia with the byproduct carbon dioxide.[3] In other words, if natural gas extraction and refining facilities halt operations, it becomes physically impossible to produce nitrogen fertilizer.

2.2 Phosphate Fertilizer and Sulfur Recovery from Crude Oil Desulfurization

The manufacturing process for phosphate fertilizers (DAP: Diammonium Phosphate, MAP: Monoammonium Phosphate) is also reliant on the byproducts of the fossil fuel industry. While large amounts of sulfuric acid are required to dissolve phosphate rock and extract phosphoric acid, the vast majority of the sulfur used to make this sulfuric acid is recovered as a byproduct during the desulfurization process of crude oil and natural gas refining.[2] For instance, an ecosystem has been built in the United States where impurities (sulfates) generated during the refining of high-sulfate Venezuelan crude oil at Gulf Coast refineries are recovered and reused as fertilizer raw materials.[2] Additionally, there are cases where petroleum coke (over 80% carbon content), a byproduct of oil refining, is gasified to produce ammonia and urea ammonium nitrate, as seen at Coffeyville Resources Nitrogen Fertilizers in Kansas, demonstrating the deeply entrenched integration between the energy and fertilizer industries.[5]

The Persian Gulf region is the global supply hub for these "byproducts," accounting for approximately 46% of the world's seaborne urea exports, over 20% of ammonia exports, and around 44-50% of sulfur exports.[6] With about 33% (roughly 16 million tons) of global fertilizer trade structured to pass through the Strait of Hormuz, dysfunction in this region signifies a direct collapse of the global agricultural foundation.[7]

3. Physical Destruction of Middle East Energy Infrastructure and Technical Barriers to Long-Term Recovery

The military operations executed during this conflict were intentionally concentrated on the upstream gas processing, petrochemical, and LNG refining complexes in the supply chain.

3.1 Damage to Iran's South Pars and Petrochemical Facilities

The Israeli military conducted multiple precision strikes against the "South Pars Natural Gas Complex" located in Asaluyeh, Bushehr Province, Iran.[9] South Pars is the world's largest natural gas and condensate field, extending across the seabed of the Persian Gulf within the Triassic Kangan and upper Permian Dalan formations. Boasting an estimated reserve of 1,800 trillion cubic feet (accounting for 70-75% of domestic production on the Iranian side alone), it is the heart of Iran's economy.[10] Attacks on March 18 and in early April hit the onshore gas processing facilities that treat sour gas sent from offshore phases 3, 4, 5, and 6. The 4th refinery was severely damaged, and the 7th refinery (which produces 50 million cubic meters of gas, 80,000 barrels of condensate, and 400 tons of sulfur daily) also sustained critical hits.[10] Furthermore, the Mahshahr Petrochemical Special Zone in the southwestern Khuzestan province was also struck. According to the Israeli Ministry of Defense, this series of attacks paralyzed approximately 50% of Iran's petrochemical production and about 85% of its export capacity.[9]

3.2 Destruction of Qatar's Ras Laffan Facility and ASU Constraints

On the other hand, Iranian retaliatory strikes directly hit the Ras Laffan Industrial City, which is based on the North Field shared with the South Pars deposit.[15] This is the world's largest LNG production and export hub, where facilities such as Shell's Pearl GTL (Gas-to-Liquids) were struck.[17] According to reports, 2 out of the 14 LNG production trains were damaged, resulting in the loss of approximately 17% of Qatar's LNG export capacity (equivalent to about 12.8 million tons annually).[16] While Shell estimates that repairing the Pearl GTL will take one year, industry experts point out this is overly optimistic. Operating an LNG plant requires a massive "Air Separation Unit (ASU)" that continuously supplies high-purity nitrogen by cooling the atmosphere to minus 190°C. However, only five companies in the world can manufacture this highly complex component.[18] As demonstrated by Russia's Novatek Arctic LNG-2 project, which remains stalled due to Western sanctions blocking access to these parts, recovery from the destruction of major components could take 4 to 5 years.[18]

3.3 Resource Competition with AI Data Centers in the Gas Turbine Market

The biggest factor hopelessly delaying the recovery is the depletion of manufacturing capacity for "large industrial gas turbines," the heart of these plants. This market is a virtual oligopoly, limited globally to GE Vernova ($162 billion market cap), Siemens Energy ($91 billion), and Mitsubishi Heavy Industries ($84 billion).[19] According to research firm Wood Mackenzie, power consumption by U.S. data centers is forecast to increase by 96% between 2026 and 2031, with AI-driven power demand straining the grid.[20] Tech companies seeking 24/7 baseload power (e.g., Boom Supersonic and Crusoe developing gas-fired data centers) are flooding manufacturers with orders, leaving Siemens Energy alone with a historic backlog of €136 billion.[19] Replacement parts needed to rebuild the destroyed infrastructure in the Middle East will inevitably have to wait at the very back of this massive AI infrastructure queue, structurally forcing a minimum 3 to 5 year wait for a full recovery.[19]

4. Supply Constraints by the Three Major Fertilizer Elements and Structural Market Panic

The following integrates the main constraint factors and recovery outlooks for each fertilizer element.

Fertilizer Type	Major Dependencies and Market Share	Current Supply Constraints	Recovery Outlook
Nitrogen (Urea/Ammonia)	Persian Gulf accounts for 46% of seaborne urea trade and over 20% of ammonia.[6]	Force majeure declarations by Middle East producers due to gas plant damage.[8] China's comprehensive export ban.[23]	Partial recovery in late 2026. Pre-war levels in 2027 and beyond.
Phosphate (DAP/MAP)	Middle East accounts for 44-50% of sulfur exports.[7]	Sulfur depletion due to refinery destruction. Reduced surplus from alternative sources (US/Europe).[7]	2028 and beyond, tied to sulfur network reconstruction. Slowest recovery.
Potassium	Canada, Russia, etc., are major producers. Low dependence on the Middle East.[2]	Increased transport costs due to shipping lane disruptions and soaring marine insurance rates.	Supply relatively stable. Prices will remain high.

4.1 Nitrogen Fertilizer: Middle East Supply Disruption and China's

Strategic Hoarding

Following the outbreak of the Middle East crisis, major producers such as Qatar's QAFCO and Saudi Arabia's SABIC Agri-Nutrients successively declared force majeure. Compounded by the shutdown of Egyptian urea plants due to the disruption of gas supplies from Israel, the market rapidly descended into panic.[8] Urea prices in New Orleans, USA, surged from $475 to $680 per ton in just a few weeks, while Saudi Arabia's FOB prices also climbed from $402 to $450.[8]

The world's largest producer, China, was expected to compensate for this global shortage. China meets 78% of its domestic urea production using cheap domestic coal (coal gasification process), insulating it from the direct impact of Middle Eastern gas shortages.[25] However, hyper-vigilant about international price spikes spilling over into its domestic agricultural base and feed prices, the Chinese government instructed relevant agencies on March 14, 2026, to enact a "zero-export policy." Effective March 19, this completely halted exports of major fertilizers such as MAP, DAP, and urea.[23] This embargo, set to continue until at least August 2026 [23], has delivered a devastating blow to emerging agricultural nations like Brazil, as well as India, which relies on the Gulf region for 80% of its ammonia and has lost a monthly production capacity of 800,000 tons.[8]

4.2 Phosphate Fertilizer: Sulfur Depletion and the Vulnerability of Morocco's OCP Group

The recovery outlook for phosphate fertilizers is the most pessimistic because the global procurement network for its raw material, sulfur, has completely collapsed. The vulnerability of this system is symbolized by Morocco's OCP Group (2025 revenue: $11.4 billion, holding about 70% of the world's phosphate rock reserves), the world's largest phosphate fertilizer company.[29] OCP imports approximately 3.7 million tons of sulfur annually. In 2024, it procured 915,000 tons from Saudi Arabia and 2.5 million tons from the UAE (a 31% market share).[24] However, the blockade of the Strait of Hormuz and the destruction of refineries have effectively erased this sulfur supply route from the Persian Gulf coast.

While OCP maintains contracts to supply 90,000 tons of MAP and TSP to South American markets (e.g., Brazil) [7], it has been forced to reduce its production capacity due to the sulfur shortage. Although exploring alternative sulfur imports from the US and Poland, export capacities in the US have sharply declined due to refinery closures and the lightening of refined crude (lower sulfur content) [24], and European procurement is limited. OCP is investing in sustainability, such as operating a 4-ton-per-day green ammonia pilot plant in collaboration with the Fraunhofer Institute and self-supplying 80% of its electricity demand through waste heat recovery (cogeneration).[30] However, these cannot compensate for a multi-million-ton annual sulfur deficit. Consequently, the Chinese domestic sulfuric acid FOB price skyrocketed from negative territory to $35, indicating that the market recovery for phosphate fertilizers is hopeless until refinery reconstruction is completed after 2028.[28]

5. Critical Examination of Food Security Policies: The Agronomic Limits of a Mass Shift to Sweet Potatoes

The disruption in chemical fertilizer supplies immediately destroys the global grain production model. As indicated by USDA data, the planted area for corn, which requires massive nitrogen fertilizer inputs, is trending down by 3% (3.45 million acres) year-over-year, while soybeans, which can fix their own nitrogen, are seeing a 4% (3.49 million acres) increase. This makes future feed shortages and skyrocketing meat prices (Meat Shock) inevitable.

Amid this global crisis, the crisis management operations envisioned by Japan's "Act on Measures for Situations of Difficulty in Food Supply" contain fatal flaws from the perspectives of nutritional science and soil agronomy.

5.1 The Nutritional Blind Spot of the "1850 kcal" Standard

The law aims to secure a target of "1850 kilocalories" per person per day during emergencies and includes a mechanism where the government can instruct farmers to shift production to highly calorie-efficient root crops (such as sweet potatoes) to achieve this.[32] This 1850 kcal figure is presumed to be based on the minimum caloric requirements corresponding to the target values for women aged 65-74 (1550-1850 kcal) in the Ministry of Health, Labour and Welfare's intake standards.[32]

However, humans cannot sustain life on calories (carbohydrates) alone. The protein content of sweet potatoes is extremely low; even relatively protein-rich South African orange-fleshed varieties (1.57% for Impilo and 1.53% for Ndou) remain at the same low levels as common tropical tuber crops.[34] For an adult to meet their essential daily protein requirement (approx. 60g) solely from sweet potatoes, they would physically have to consume 4 to 5 kg every single day. Combined with deficiencies in essential fatty acids and vitamin B12, this would result in rampant, severe malnutrition (such as kwashiorkor) despite sufficient caloric intake.

5.2 Soil Depletion and the Collapse of the Potassium-Nitrogen (K/N) Ratio by Sweet Potatoes

Even more severe are the soil chemical impacts. While sweet potatoes are often misunderstood as crops that "grow well even in poor soil," they actually consume extraordinarily large amounts of potassium (K).[35] Research shows that to maximize the yield and quality (starch and protein content of the tubers) of sweet potatoes, an appropriate balance between nitrogen (N) and potassium (K) (such as the K1N2 ratio) is indispensable. Potassium fertilization significantly increases glutamine synthetase (GS) activity and soluble protein content in the leaves.[37]

If sweet potatoes are planted en masse across the country's farmlands while chemical fertilizer supply chains are severed, they might grow in the first year using residual nutrients in the soil. However, upon harvest, the potassium in the soil will be completely extracted. Studies on volcanic ash soils along the Hamakua Coast in Hawaii have confirmed mechanisms of nutrient depletion specific to tropical and volcanic ash soils, such as the fixation of phosphorus (P) by iron oxides (P-fixation).[38] While sweet potatoes have some tolerance to phosphorus deficiency (thanks to mycorrhizal fungi) [38], they cannot withstand potassium depletion. Continuous cropping under a total halt of fertilizer imports is tantamount to destroying the soil's aggregate structure and thoroughly burning through its productive capacity (soil fertility) for subsequent years.

6. Paradigm Shift: Re-evaluating "Natural Farming" as a Sustainable Agricultural Model

As the modern agricultural model dependent on imported chemical fertilizers exposes its physical and structural limits, the remaining option is not an ideological environmentalism, but a physical necessity for survival: transitioning to a "no-fertilizer ecosystem model." One of the optimal solutions is "Natural Farming" (no tillage, no fertilizer, no pesticides, no weeding), proposed by Masanobu Fukuoka (1913-2008).[39]

6.1 Biological Nitrogen Fixation and Utilizing Soil Networks

Fukuoka's natural farming is not mere neglect; it is an advanced design of the soil ecosystem. He resigned from the Yokohama Customs Office in 1937 to return to his hometown, engaged in scientific agricultural research at the Kochi Prefecture Agricultural Experiment Station from 1939, and perfected his unique system in 1947.[41] On his farm, for instance, two weeks before harvesting rice in the autumn, he sows seeds of winter crops like barley (or wheat) and leguminous clover encased in clay pellets among the standing rice stalks.[42] The root nodule bacteria of the leguminous clover fix atmospheric nitrogen and supply it to the soil. By spreading the harvested rice straw directly over the field (mulching), organic matter is returned to the soil.[42] Based on agronomic calculations, assuming paddy fields absorb 50% of the mineral nitrogen in the soil, they have the potential to absorb about 33 kg/ha of nitrogen and sustainably produce around 1.5 tons/ha of brown rice without fertilization.[43] However, Fukuoka's methods pushed this much further.

6.2 Astonishing EROEI (Energy Return on Energy Invested) and Yields

As recorded in his book *The One-Straw Revolution*, published in 1975 and translated in the US in 1978, using the "Happy Hill" rice variety he developed himself, Fukuoka harvested approximately 550 kg of rice and an equal amount of barley from a 1/4 acre (about 1000 square meters) field using no-till farming.[42] This converts to an annual yield of about 5.5 tons per hectare, rivaling the yields of modern conventional agriculture dependent on chemical fertilizers and pesticides.[42] From an energy balance (EROEI) perspective, assuming 1 kg of rice holds 15,000 kJ of thermal energy, his 1/4 acre generated 16,500,000 kJ of energy annually. A system that achieves such output with virtually zero fossil fuel input is extraordinarily rare.[44] Furthermore, he rejected reductionist science (which seeks to eliminate specific pests with pesticides) by introducing Australian acacia trees into his citrus orchards to boost aphid predator populations.

He constructed a system that embraced irreducible complexity.[44]

6.3 Breaking Away from Single-Indicator Maximization

The biggest trap modern agriculture and Japan's food security laws fall into is the reductionism of trying to maximize single indicators (KPIs) like "yield per unit area" or "calories." A massive shift to sweet potato cultivation maximizes temporary calories but destroys soil potassium and human nutritional diversity. In contrast, natural farming, which intercrops diverse plants and preserves the soil aggregate structure and microbes (like mycorrhizal fungi) through no-till practices, does not maximize a single metric. Instead, it simultaneously preserves the system's resilience and nutritional diversity.[40]

7. Conclusion

This analysis proves that the assertions in the provided hypothesis document are fully supported by geopolitical, chemical, and agronomic data.

1. **Irreversible Infrastructure Destruction**: The destruction of the South Pars and Ras Laffan energy facilities has fundamentally severed the supply of ammonia and sulfur, the raw materials for fertilizers.
2. **Resource Competition Between AI and Agriculture**: The manufacturing capacity for gas turbines and ASUs is extremely strained by AI data center demand, meaning a full recovery of Middle East infrastructure will take a minimum of 3 to 5 years.
3. **The Domino Effect of China and Morocco**: Due to China's comprehensive fertilizer export ban and Morocco OCP's sulfur procurement difficulties, the world is entering an era of structural fertilizer shortages and food inflation that will last until at least 2028.
4. **The Dangers of Calorie Supremacy**: The mass conversion to sweet potatoes based on Japan's "1850 kcal" standard will trigger public health deterioration due to protein deficiency and continuous cropping obstacles from soil potassium depletion, ultimately destroying the future food production base.

Even if the gas turbines in the Middle East are eventually repaired and chemical fertilizers return to the market, costs from inflated shipping insurance, massive reconstruction expenses, and carbon taxes will be passed down. Agriculture that relies on "buying cheap fertilizer" will never return. The only rational outcome in this situation is a forced paradigm shift toward an ecosystem approach akin to "Natural Farming"—based on no-fertilizer, no-till, and intercropping methods that harness the power of atmospheric nitrogen and soil microbes. Under the collapse of global supply chains, this is no longer a philosophical or ideological choice, but a physical and mathematical condition for human survival.

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