



Guano Supply Chains: Historical Lessons on Agricultural Resource Dependence

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Abstract: Guano, a natural fertilizer derived from seabird excrement, is exceptionally rich in phosphates, nitrates, and potassium, essential for crop growth and soil restoration. In the nineteenth century, Peru's islands contained vast deposits that fueled intensive agriculture, particularly in Europe. Extraction relied on immigrant labor under harsh conditions and required sophisticated coordination among local producers, traders, and maritime carriers. Exposure to storms, piracy, and political conflicts demonstrated that economic strength alone could not secure export flows. Reliance on a limited number of islands made supply chains highly vulnerable, highlighting the necessity of diversifying sources and maintaining strategic reserves. The guano trade provides early evidence that resilient agricultural commodity chains depend on proactive planning, logistical flexibility, and multi-stakeholder collaboration. Lessons from this historical case offer a framework for modern agricultural systems to withstand environmental, economic, and geopolitical shocks. By emphasizing anticipation, diversification, and operational margins, the guano case illustrates how continuity of procurement and agricultural productivity can be preserved, providing actionable insights for contemporary food security, sustainable fertilizer management, and the strategic handling of critical resources.

Keywords: Agriculture, critical resources, food security, guano, history, logistics, resource dependence, supply chain.

INTRODUCTION

Guano, a natural fertilizer produced primarily from accumulations of seabird, bat, and other animal droppings, forms on islands and isolated coastal zones under unique environmental conditions, creating deposits of extraordinary density and longevity, sometimes several meters thick. Its nutrient composition, particularly the abundance of phosphates, nitrates, and potassium, renders it exceptionally effective for stimulating plant growth and restoring exhausted soils [30]. Variations in quality reflect the biological origin of the excrement and the mineral makeup of the underlying terrain, yet even lower-grade deposits maintain significant agronomic value. During the nineteenth century, rising agricultural intensification in Europe and the Americas—driven by soil depletion and the demand for higher yields—positioned guano as a central input for productivity enhancement, catalyzing transformations in land management and fertilization strategies. Beyond its chemical properties, guano's solubility facilitated rapid nutrient assimilation by crops, enabling short- and long-term improvements in plant development [26]. Integrated nutrient management approaches, combining organic amendments with nitrogen inputs, further amplified these effects, enhancing soil structure and overall fertility [16]. The accumulation, extraction, and global transport of guano therefore illustrate early recognition of the complex interplay between natural resource availability, agricultural demands, and human intervention, providing a lens for understanding the mechanisms required to translate localized natural

wealth into sustained agricultural productivity and for anticipating modern challenges in soil management and nutrient optimization.

During the nineteenth century, the Peruvian guano trade represented one of the first large-scale international flows of a critical raw material, linking the Chincha and Lobos de Afuera Islands to distant European and American markets [6]. Extraction demanded a labor-intensive workforce, often composed of immigrants subjected to extreme and coercive conditions, while coordination among local operators, trading houses, and shipping firms required meticulous attention to timing, storage, and transport logistics [22]. Maritime risks, including storms, rogue waves, and piracy, compounded the vulnerability of each shipment, and fluctuating global demand amplified economic uncertainties [2][3]. The concentration of deposits and reliance on few islands intensified systemic fragility, prompting the development of trade monopolies, long-term contracts, and partial military protection to safeguard critical flows [15] (see Box 1 for a concise overview of the rise and decline of guano as a *globally critical resource*). Strategic alignment between production capabilities and global agricultural needs thus emerged as a central challenge, illustrating the inherent tension between local resource control and international demand. Beyond its immediate agricultural value, guano functioned as a laboratory for global economic coordination, demonstrating that secure and efficient commodity chains require foresight, adaptive management, and multi-layered organization. Lessons from this experience foreshadow contemporary supply chain vulnerabilities, particularly for resources whose geographic concentration and strategic importance magnify exposure to disruption, highlighting the enduring relevance of flexibility, redundancy, and operational oversight in securing essential commodities.

The historical guano trade offers striking parallels with modern critical resource management, where localized extraction of strategic materials such as lithium, rare earth elements, or energy commodities generates systemic risks across global markets [1][13]. Just as control over guano and nitrate deposits provoked legal and economic conflicts, contemporary supply chains face pressures from concentrated production, geopolitical disputes, and market volatility. The nineteenth-century experience reveals that technical or operational sophistication alone cannot ensure resilience: dependency on a narrow set of production sites increases vulnerability to shocks, whether arising from environmental hazards, political unrest, or economic fluctuations [11][28]. Mitigation strategies employed during the guano era—including redundancy in transport routes, diversification of storage locations, and coordinated multi-stakeholder management—demonstrate early principles of risk management still applicable today. Secure inventories, proactive monitoring, and flexible logistical planning enabled the preservation of procurement continuity, illustrating how agricultural production can be maintained despite disruptions. The trade underscores the critical importance of anticipating weak signals, structuring contingency measures, and aligning operational practices with broader socio-political and ecological realities. By examining such historical mechanisms, contemporary managers gain insight into designing resilient agricultural and industrial systems capable of adapting to unforeseen challenges, ensuring continuity in both the movement of materials and the stability of dependent economies.

The guano case also illuminates the structural characteristics of supply chains as *socio-economic* and *political* constructs, rather than merely technical infrastructures. Geographic concentration of critical inputs created inherent fragility, requiring mediation

through legal frameworks, commercial agreements, and government interventions to stabilize flows subject to natural and human uncertainties [12]. This extractive dependence simultaneously reinforced economic growth and heightened vulnerability, demonstrating the double-edged nature of specialization. Observing interactions among laborers, merchants, intermediaries, and environmental constraints reveals supply chains as dynamic systems integrating ecological, economic, and political dimensions. Management strategies were thus not limited to operational efficiency but extended to governance, regulation, and multi-actor coordination, emphasizing the anticipatory planning necessary to secure scarce resources. The historical guano trade exemplifies how resilience emerges from the combination of diversification, logistical flexibility, and strategic oversight, with insights directly translatable to contemporary agricultural procurement networks, energy distribution, and industrial resource management. Framing dependency as a structural property rather than an aberration provides a lens for understanding contemporary vulnerabilities, offering guidance for the design of robust, adaptive, and sustainable supply chains capable of maintaining continuity, mitigating risk, and supporting global production under conditions of uncertainty. The case underlines then the enduring relevance of early resource management practices for contemporary global systems.

Box 1: Guano: The First Globalized Fertilizer

In the nineteenth century, guano emerged as a critical resource at the heart of the first wave of globalized agriculture. Harvested primarily from islands off the coast of Peru, it became within decades an indispensable input for European and North American farming, which faced widespread soil depletion. Its exceptional nutrient content made it the most effective fertilizer available, driving rapid gains in crop yields. This growing dependence shaped a globalized market centered on a geographically concentrated resource. Peru, the main producer, derived the bulk of its national revenue from the guano trade, while international networks coordinated extraction, transport, and large-scale distribution. The strategic value of guano was such that it sparked diplomatic tensions and economic rivalries, revealing early the stakes involved in controlling critical raw materials. Yet the model carried inherent vulnerabilities: intensive exploitation gradually exhausted the most accessible deposits, while reliance on a single resource exposed both producers and markets to financial and political instability.

As production expanded, debt mechanisms and institutional fragility further undermined the system. By the 1870s, several factors accelerated guano's decline. The rise of alternative sources—particularly mineral phosphates mined in North Africa and North America—offered more abundant and geographically diversified supplies. At the same time, advances in agricultural chemistry began a shift toward industrial fertilizers, less dependent on specific natural conditions. Within a few decades, guano went from a globally strategic resource to a marginal commodity. This historical episode illustrates one of the first complete cycles of a critical raw material: rapid emergence, global dominance, and technological substitution. It highlights the risks of geographic concentration and underscores the enduring importance of diversification and innovation in building resilient production systems.

Source: Adapted from *Les Echos*, August 6, 2019.

A PIONEERING TRADE

The guano trade positioned Peru as a central player in the nineteenth-century global economy, as the resource constituted both the country's main export and the basis of its public revenue, while also bolstering its international financial credibility [20]. This

dependence was closely linked to strong British demand, where guano quickly became a preferred fertilizer due to its high solubility and agronomic effectiveness, enabling rapid crop growth. Beyond its economic dimensions, this trade was part of a global transformation of the relationship between labor and the environment, marked by the massive circulation of nitrogen fertilizers and the mobilization of forms of forced labor on a transnational scale, revealing an early “*green revolution*” as early as the nineteenth century [21]. However, it relied on a particularly brutal system of exploitation, based on the massive use of contract labor—particularly Chinese workers—subjected to extreme working conditions often amounting to a form of structural coercion, revealing the profoundly violent human face of this extractive economy [23]. The combination of high production intensity and rudimentary planning created a critical dependency and exposed the system to natural and political disruptions. Internal tensions, regional conflicts, and international pressure underscored the geopolitical role of guano, far beyond its economic value.

Maritime transport of guano emerged as a critical node in the supply chain, as vessels contended with storms, volatile currents, and the gradual hardening of cargo, rendering each voyage inherently risky. In response, traders implemented a range of pragmatic innovations to mitigate these hazards, including the installation of wooden rails and chutes on the islands, the use of seasonal storage facilities, and the coordination of ship rotations, thereby enabling quasi-industrial throughput within a largely pre-industrial context [23]. For instance, Figure 1, dating from the early 1860s, depicts loading cars filled with guano at the Chincha Islands, closely resembling systems later observed in numerous European mining operations.



Figure 1: Loading cars with guano at the Great Heap, Chincha Islands (c. 1860)

Source: Photo by Henry Moulton, Bibliothèque nationale de France, Paris.

Foreign trading houses, such as Gibbs, played a pivotal role by providing financing, organizing logistics, and managing political risk, underscoring the importance of intermediaries in ensuring continuity of supply [29]. Periodic disruptions—whether driven by

local conflicts or fluctuations in production—required swift reconfiguration of flows, the mobilization of secondary sources, and the redirection of shipments to alternative ports, revealing an early form of organizational agility [19]. Overall, the intensity of logistical coordination suggests that the guano trade extended well beyond commodity exchange, constituting a highly integrated global system in which performance and supply security were mutually reinforcing [4].

The trajectory of the guano trade, including its rise and decline, is illustrated in Figure 2 which provides a visual representation of the economic dynamics that shaped Peru's golden age of guano exports. Revenues from guano exports financed the Peruvian State and strengthened its position in global trade, yet the geographic concentration of deposits on a few isolated coastal islands made the economy extremely vulnerable: any local disruption—whether weather conditions, conflicts, logistical problems, or political tensions—could interrupt production, jeopardize public revenues, and trigger fluctuations in international markets [11]. Moreover, control of guano islands and neighboring fertilizer resources played a central role in international rivalries, culminating in the War of the Pacific (1879-1883), where territorial and economic disputes surrounding guano and nitrate exports contributed to sustained military tensions, illustrating the interdependence between critical resources and geopolitics [13]. The United States, through the Guano Islands Act of 1856, claimed and placed under American jurisdiction numerous guano-rich islands, ensuring access to strategic deposits essential for agriculture and international trade. As Duffy Burnett [9] observes, this legislation reflects early awareness of the security of vital resource flows, with the United States using it not only to safeguard fertilizer supplies for its economy but also as an instrument for projecting power and influence along global trade routes.



Figure 2: Rise and Fall of Guano for Peru

Source: Cushman [6].

Financial and logistical flows eventually adapted to market pressures, introducing preventative measures such as quotas, directed exports, and monopolistic arrangements, demonstrating the importance of organization and planning in maintaining economic

stability. Beyond economics and geopolitics, the “*guano system*” offers critical lessons for the management of essential agricultural resources. Disruptions caused by maritime conditions, conflicts, or labor shortages encouraged actors to create redundancies, diversify storage points, and secure transport contracts, reflecting an early systemic approach to supply chain resilience [28]. The scale of flows, illustrated in Figure 2, and the complexity of stakeholders reveal that resilience depended not only on technological capacity but also on firms’ ability to adapt quickly to disruptions by modifying inputs, revenues, and supply sources, as evidenced by the Pacific Guano Company’s response to the collapse of the menhaden fishery in 1879 [25]. Table 1 summarizes the main historical challenges faced in the guano trade and the strategies implemented to manage them, offering a clear framework for understanding the pioneering nature of global coordination. This case underlines how guano served as a model in which meticulous logistical planning and the security of flows were essential for both economic and geopolitical stability.

Table 1: Guano Trade: Challenges and Responses

Dimensions	Historical guano challenges	Implemented strategies
<i>Economic</i>	Dependence on the British market, concentrated public revenues, price volatility	Commercial contracts, quotas, directed exports, partial diversification of trading partners
<i>Logistical</i>	Hazardous maritime transport (storms, rogue waves, piracy), perishable cargo, distant ports	Wooden rails and chutes on islands, seasonal warehouses, rotational shipping schedules, coordination with foreign trading houses
<i>Human</i>	Coercive labor, extensive use of Chinese workers, extreme working conditions	Supervision and workforce management, partial regulation of labor rotations, adaptation to human and ecological flows
<i>Geopolitical</i>	Regional conflicts, War of the Pacific, international claims (Guano Islands Act)	Strategic control of islands, commercial alliances, State interventions to secure access to resources

Source: Own elaboration.

BETWEEN DEPENDENCE AND VULNERABILITY

Dependence on guano exposes the profound structural fragility inherent to the earliest global supply chains, revealing the vulnerability of systems that relied on highly localized resources, complex networks of actors, and intricate transoceanic logistics. The Peruvian monopoly over the Guanera Islands magnified such risks, as any disruption—whether environmental, political, or operational—propagated rapidly through international agricultural markets, affecting not only commodity flows but also public revenues and national economic stability [12]. Natural hazards, including erosion of guano deposits, cyclonic storms, and shifting ocean currents, frequently interrupted supply, while internal conflicts, administrative inefficiencies, and regional instability further complicated planning and accessibility [26]. Traders confronted seasonal fluctuations in extraction rates, compelling them to adopt storage strategies that were inherently limited and often insufficient to satisfy the burgeoning European and American demand for high-quality fertilizer [17]. Interactions with foreign trading houses introduced secondary dependencies, as intermediaries provided financing, oversaw distribution, and imposed contractual obligations that constrained local decision-making. Such a concentration of critical

resources underscores how economic prosperity rested on a precarious equilibrium in which wealth and systemic vulnerability coexisted. The guano case demonstrates that the concentration of a strategic agricultural resource inherently magnifies systemic risks, highlighting the necessity of resilience mechanisms and proactive coordination even in highly lucrative trade flows.

The logistics underpinning guano transport amplified the fragility of these global supply chains. Each shipment navigated vast and unpredictable maritime spaces, facing shipwrecks, piracy, and detours imposed by geopolitical conflicts, which collectively transformed routine commerce into a high-risk endeavor [11]. Production disruptions or blockades at source locations led to sudden shortages in European and American ports, demanding immediate route adjustments, flexible allocation of cargo, and negotiation of alternative sources [19]. Coordination and logistical adaptability proved essential, as economic robustness alone could not guarantee continuity of supply. Human and ecological systems played active roles: Hawaiian migrant workers contributed labor-intensive extraction and transport processes, while seabird populations shaped the deposition and accumulation of guano across different temporal and spatial scales [24]. Measures such as militarization of shipping lanes, creation of monopolistic trade arrangements, and partial diversification to additional islands exemplify early multi-level strategies to mitigate these vulnerabilities. The guano trade illustrates that the resilience of a resource-dependent agricultural commodity chain depends as much on social organization, ecological understanding, and adaptive management as on technological capacity or economic investment.

The vulnerabilities observed in the nineteenth-century guano trade resonate powerfully with contemporary global supply chains. Dependence on a single production site produces systemic risks comparable to those associated with oil, lithium, or critical rare earth elements, revealing a persistent structural fragility in resource-dependent systems [15]. Maritime shipments continued to confront rogue waves, piracy, and unpredictable weather, while interruptions in extraction or political conflicts provoked shortages that reverberated across Europe and the Americas [19]. Coordination and flexibility remained essential: the complex interplay between labor forces, ecological dynamics, and island environments required constant adaptation, illustrating that economic strength alone does not secure procurement continuity [24]. This historical example aligns with recent analyses of dryland food chains, which highlight the vulnerability of production systems to multiple, simultaneous shocks, whether natural, socioeconomic, or institutional [10]. The strategic significance of geographic concentration is underscored by contemporary parallels, such as the blockade of the Strait of Hormuz in March 2026, which disrupted approximately 35 percent of global nitrogen fertilizer flows, directly threatening European agricultural output (see Figure 3) (see Box 2 for a detailed overview of how modern fertilizer commodity chains mirror the vulnerabilities observed in the nineteenth-century guano trade). By drawing lessons from the guano trade, it becomes evident that proactive measures—including redundancy, diversification, and operational flexibility—are critical to securing supply chains and maintaining resilience in the face of systemic risks, offering timeless insights into the management of globally interconnected agricultural systems.

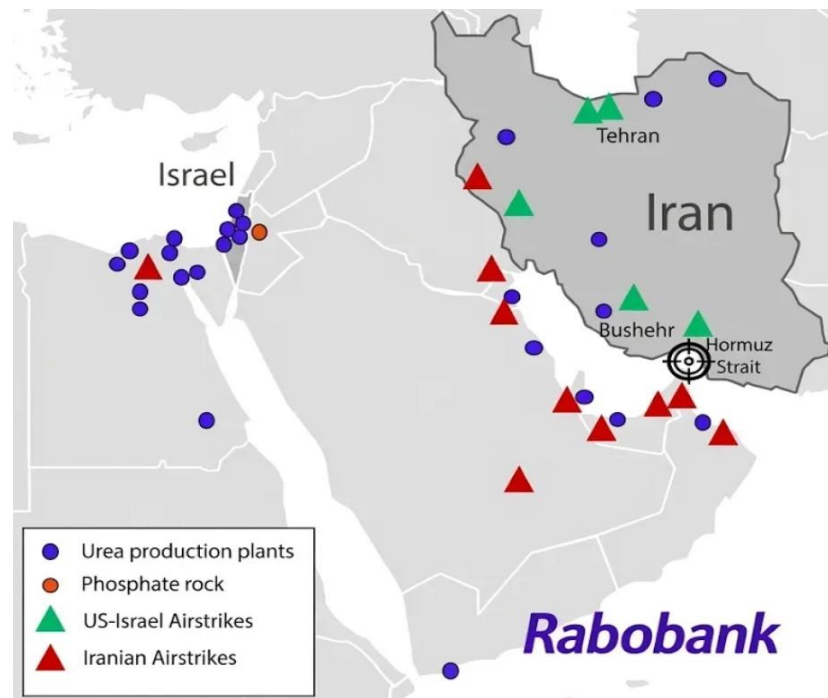


Figure 3: Regional Fertilizer Production Facilities and Airstrikes (March 2026)

Source: RaboResearch (2026).

Box 2: The Strait of Hormuz and Global Fertilizer Vulnerability

The Strait of Hormuz is a strategic chokepoint for global trade, concentrating the transit of essential commodities such as oil, natural gas, and, critically, fertilizers. A prolonged disruption in this maritime corridor—particularly for the shipment of urea, ammonia, ammonium nitrate, and phosphates—could have far-reaching consequences for agriculture worldwide and food markets. A substantial share of these fertilizers, produced in the Gulf, relies on passage through the strait to reach major agricultural regions across Asia, Europe, and the Americas. When shipments are interrupted, fertilizer prices spike, directly impacting the cost of staple crops like wheat, corn, and rapeseed. Some countries maintain reserves that buffer short-term shocks, but many remain exposed, heightening the risk to food security, particularly in poorer nations. This situation underscores the global vulnerability created by geographic concentration of critical agricultural inputs and highlights the importance of procurement diversification, strategic stockpiling, and logistical planning to safeguard crop production and market stability.

Source: Adapted from *Time France*, March 6, 2026.

WHAT LESSONS CAN BE LEARNED?

Delving into the history of the nineteenth-century guano trade yields a set of analytically rich insights for contemporary global supply chains, particularly in relation to the management of critical agricultural inputs. The concentration of extraction on a limited number of Peruvian islands exemplifies a structural exposure inherent in spatially confined resource bases, where localized disruptions can cascade across international markets. Such a configuration illuminates the enduring tension between geographically anchored production and geographically dispersed demand, a challenge that continues to shape the circulation of fertilizers and other essential inputs. The coordination required to move guano across oceans toward distant agricultural regions prefigures the complexities of multi-

country logistics, inventory positioning, and temporal synchronization, while underscoring that technological sophistication alone cannot compensate for insufficient redundancy. Episodes of war, nationalization, or market instability reveal how reliance on a single source magnifies systemic risk and compels economic actors to develop anticipatory strategies. In that respect, the nineteenth-century experience demonstrates that resilience emerges less from scale than from the capacity to reconfigure procurement architectures under stress, offering a historically grounded framework that remains directly relevant for designing adaptive and secure agricultural systems [8].

The logistical lessons derived from the guano trade extend with remarkable clarity to present-day industrial organization, particularly in sectors exposed to volatile procurement conditions. Periodic shortages linked to extraction constraints or transport interruptions underscore the necessity of maintaining strategic reserves and cultivating alternative sourcing arrangements, as illustrated by the gradual diversification of guano-producing islands during the nineteenth century [25]. Overreliance on single suppliers, whether defined by specific extraction sites or transport nodes, reveals the importance of developing monitoring capabilities capable of identifying early signals of disruption and enabling timely adjustments in procurement and distribution strategies [13]. Historical precedents further indicate that State intervention can simultaneously stabilize access and generate geopolitical frictions, as exemplified by the Guano Islands Act, a dynamic that resonates with contemporary tensions surrounding rare earth elements and other strategic commodities [7]. The organization of guano flows, involving specialized labor and intermediary actors, anticipates modern patterns of subcontracting and outsourcing, where coordination across multiple stakeholders becomes a central condition of resilience. Increasing fragmentation of production and distribution processes reinforces the need for integrated governance mechanisms capable of securing flows while maintaining flexibility, particularly in agri-food systems where each stage introduces potential vulnerabilities [27].

Insights drawn from the guano trade ultimately extend into the domain of strategic resource management, where the interplay between environmental constraints, economic imperatives, and political considerations becomes especially salient. The Peruvian case demonstrates that spatial concentration and supplier dependence amplify the consequences of localized shocks, whether arising from ecological degradation, armed conflict, or financial instability, thereby necessitating mitigation approaches that integrate multiple dimensions of risk [14]. Over time, the organization of guano extraction evolved from unregulated exploitation toward a more structured system overseen by technical experts, reflecting an early recognition of the need to align operational practices with ecological knowledge [5]. Such institutionalization contributed not only to stabilizing export flows but also to preserving fragile island ecosystems, highlighting the role of scientific expertise in shaping sustainable procurement regimes.

As indicated in Table 2, historical patterns translate into a set of principles with direct contemporary relevance, linking past experience to present-day strategic design. Resilience, in that sense, rests on anticipatory governance, diversification of supply bases, and the creation of operational slack, combined with sustained attention to environmental and social externalities [17]. Far from a historical curiosity, the guano trade offers a rigorous analytical lens through which to rethink the governance of critical resources in an era marked by systemic uncertainty.

Table 2: Key Lessons from the Nineteenth-Century Guano Trade

Historical principles	Contemporary implications	Illustrative examples
<i>Concentration of critical resources increases systemic risk</i>	Diversify suppliers and geographic sources of critical materials	Guano from limited Peruvian islands; modern parallels with rare earth minerals
<i>Dependence on single transport routes heightens vulnerability</i>	Build redundancy in logistics and multiple distribution channels	Ocean shipments of guano affected by storms and piracy; modern supply chain rerouting during the Strait of Hormuz blockage
<i>Disruptions in production require proactive mitigation</i>	Maintain strategic stockpiles and contingency planning	Seasonal fluctuations in guano extraction; today's fertilizer reserves and alternative sourcing
<i>Coordination across multiple actors ensures resilience</i>	Invest in multi-stakeholder collaboration and oversight	Migrant labor, intermediaries, and merchants in guano trade; today's coordinated global procurement networks
<i>Geopolitical tensions impact resource security</i>	Anticipate and manage international risks through policy and alliances	Guano Islands Act and the War of the Pacific; contemporary trade restrictions and export controls

Source: Own elaboration.

CONCLUSION

The persistence of resource dependence in agriculture remains a defining concern in a world tasked with feeding an estimated 8.3 billion people by 2026, and revisiting the nineteenth-century guano trade offers a particularly revealing lens through which to interrogate that challenge. Concentration of a critical input within a narrowly bounded geographic space exposes food procurement systems to cascading disruptions, demonstrating how localized shocks can propagate across global markets. Maritime transport under uncertain conditions further underscores that apparent logistical sophistication provides no guarantee of robustness when structural exposure remains unaddressed. Close examination of the guano trade highlights the dense web of interdependencies linking actors, locations, and material flows, and points to the necessity of identifying latent fragilities before they crystallize into systemic breakdowns. Such insights resonate strongly in contemporary contexts characterized by intensified globalization and continued reliance on spatially concentrated inputs. Mechanisms historically deployed to secure guano circulation reveal that resilience emerges not solely from technological capability, but from the capacity to anticipate disruptions, incorporate operational buffers, and continuously recalibrate procurement configurations in response to evolving risks.

Analysis of the guano trade further demonstrates that supply chain resilience is fundamentally an organizational and strategic construct, shaped by the interplay of planning, flexibility, and diversification. Even highly profitable systems can prove structurally brittle when dependence on a limited set of suppliers or regions becomes entrenched, as illustrated by Peru's experience during the height of guano exports. A comprehensive perspective is therefore required, one that integrates environmental hazards, geopolitical tensions, and market volatility into a unified analytical framework. Conceptualizing supply chains as dynamic meta-organizations allows for a more nuanced

understanding of how interactions among firms, infrastructures, and regulatory environments generate both stability and fragility. Effective mitigation strategies must operate across multiple dimensions, combining anticipatory planning, scenario-based preparation, and continuous responsiveness to weak signals of disruption. Historical analysis in this context serves not merely as retrospective interpretation but as a means of refining core concepts such as systemic vulnerability, thereby informing the design of more adaptive and robust procurement architectures suited to the complexities of twenty-first-century resource circulation.

Beyond its historical specificity, the guano case provides a compelling framework for rethinking the governance of agricultural inputs under conditions of uncertainty and constraint. Geographic concentration and relative scarcity emerge as central drivers of systemic risk, reinforcing the urgency of developing mechanisms capable of stabilizing flows across fragmented and interdependent networks. Practices observed during the nineteenth century, including multi-actor coordination, strategic stock management, and diversification of delivery points, offer enduring insights for contemporary agricultural logistics, where fertilizers, seeds, and other critical inputs often remain tied to limited production zones. Integration of strategic foresight with operational flexibility appears essential for mitigating the effects of environmental disruptions, economic volatility, and geopolitical tensions. Such principles hold particular relevance for the development of resilient and sustainable agricultural systems, capable of maintaining productivity under adverse conditions. Far from constituting a purely historical inquiry, examination of the guano trade contributes to a forward-looking agenda, providing a robust conceptual foundation for designing food supply chains that can absorb shocks, adapt to uncertainty, and support long-term food security in an increasingly volatile global environment.

ACKNOWLEDGMENTS

The author gratefully acknowledges the sustained support of the CERGAM Lab, Aix-Marseille University, in advancing research in supply chain management, and extends particular appreciation to Daisy Bertrand, head of the Entrepreneurship, Information, and Internationalization research stream, for her valuable encouragement.

CONFLICT OF INTEREST

The author declares no conflict of interest related to the publication of this manuscript and confirms that no financial support was received that could have influenced its findings.

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