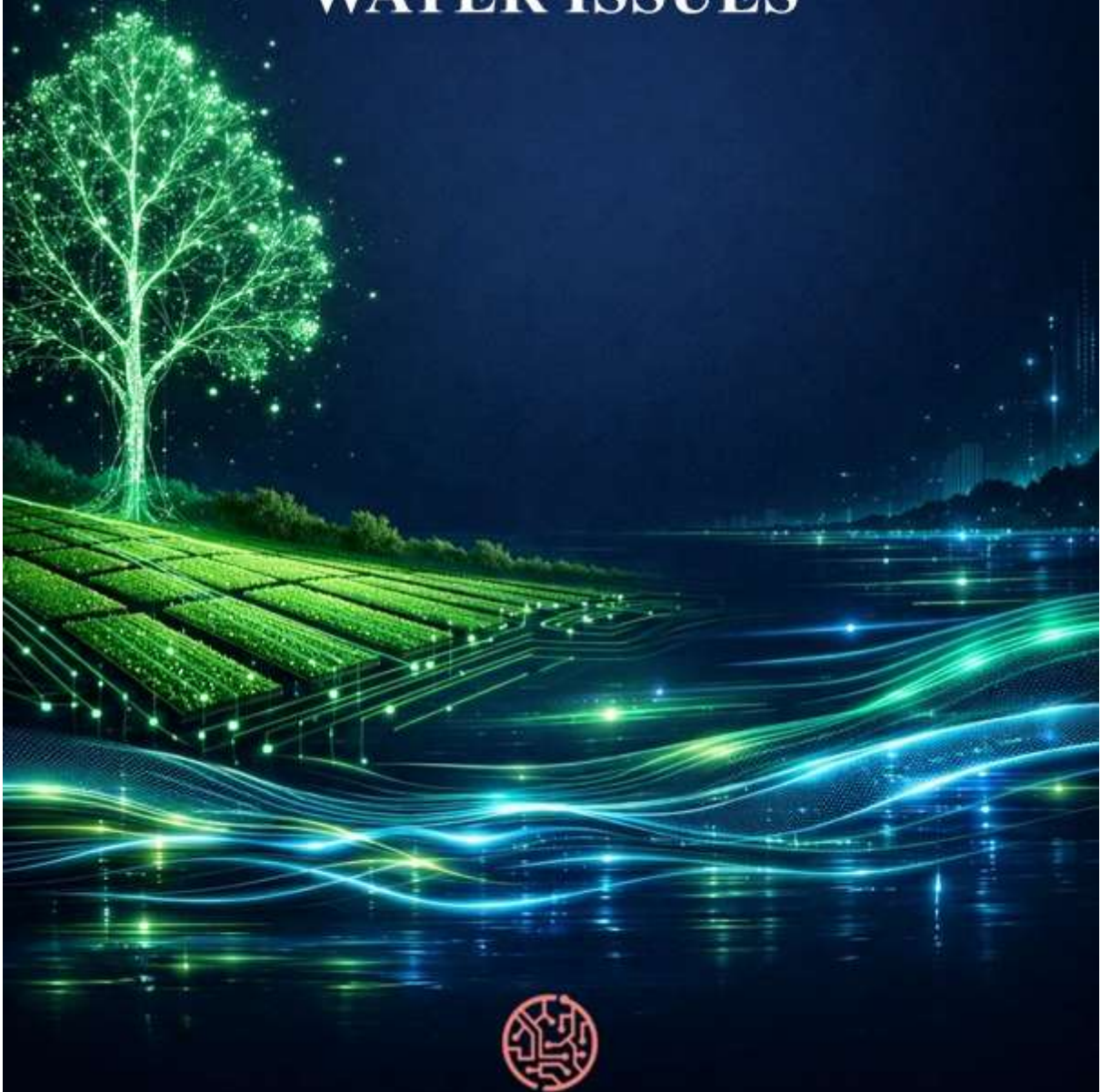


CONTEMPORARY AND INNOVATIVE RESEARCH IN AGRICULTURE, FOREST AND WATER ISSUES



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***CONTEMPORARY AND
INNOVATIVE RESEARCH IN
AGRICULTURE, FOREST
AND WATER ISSUES***

Editor

Prof. Dr. NİGAR YARPUZ BOZDOĞAN





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Geopolitical Shocks and Agricultural Resilience: Lessons from the Pandemic and the Russia Ukraine War for Turkish Agriculture under a New Iran Centered Conflict

İsmail Bülent Gürbüz ¹

1- Doç. Dr.; Uludağ Üniversitesi Ziraat Fakültesi Tarım Ekonomisi Bölümü. bulent@uludag.edu.tr ORCID No: 0000-0001-5340-3725

ABSTRACT

Recent global crises including the COVID-19 pandemic, the Russia–Ukraine war, and the emerging Iran, US–Israel conflict have exposed structural vulnerabilities in global food systems. This study examines how successive geopolitical shocks affect agricultural economies, with a specific focus on Turkish agriculture. The aim is to analyze how disruptions in energy markets, fertilizer supply, logistics networks, and exchange rate dynamics transmit war-related shocks to agricultural production costs, food prices, and sectoral resilience. The study employs a qualitative analytical framework based on a comprehensive review of international literature on geopolitical risk, war economies, food security, and food supply chains. The findings indicate that modern agricultural systems are increasingly integrated with global energy, fertilizer, financial, and logistics networks, making them highly sensitive to geopolitical disruptions. In the short term, rising energy prices, fertilizer supply constraints, higher feed costs, and increasing logistics expenses may significantly increase production costs. In the long term, persistent geopolitical instability may alter cropping patterns, reduce agricultural investment incentives, and contribute to persistent food inflation. By analyzing multiple crises within a single framework, the study highlights the cumulative nature of geopolitical shocks and emphasizes the need to strengthen agricultural resilience through reduced input dependency, improved risk management mechanisms, and more diversified supply structures.

Keywords – war economy; supply chain; Russia and Ukraine war; Iran US and Israel conflict; Turkish agriculture; food inflation; fertilizer; energy; resilience

INTRODUCTION

A war economy does not merely entail an increase in defense spending or the redirection of public budgets toward military priorities; it is simultaneously a multilayered process wherein price formation, trade routes, energy and food markets, expectations, financial risk premiums, and the distribution of social welfare are fundamentally reshaped. Recent literature demonstrates that the effects of wars and geopolitical tensions are no longer confined to conflict zones; on the contrary, they rapidly permeate the global economy through commodity markets, global supply networks, and financial channels. The addition of the Russian and Ukraine war to the supply side vulnerabilities that emerged in the post pandemic period has re-centered discussions on the war economy.

The first notable point in this emerging literature is that the relationship between geopolitical risk and commodity prices has acquired a structural, rather than exceptional, character. Saâdaoui, Ben Jabeur, and Goodell (2022) examine crisis periods such as Brexit, COVID 19, and the Russia-Ukraine war collectively, revealing a significant causality from geopolitical risk to basic food prices. Conversely, Goyal, Mensah, and Steinbach (2024) show that geopolitical risk does not exert a homogeneous effect across agricultural commodity markets; rather, this effect varies depending on the storability, substitution potential, and market structure of the product (Gürbüz and Özkan, 2021). Similarly, Aizenman, Lindahl, Stenvall, and Uddin (2024) note that event based geopolitical shocks related to the Russia-Ukraine war have produced rapid and measurable impacts on wheat and natural gas prices, whereas the magnitude of the effect varies for other products. These findings are crucial in demonstrating that a war economy does not affect all goods equally; it yields more intense and enduring consequences for strategic products.

The impact of a war economy on inflation is explained not merely through excess demand, but largely via supply side and cost push dynamics. Asadollah, Carmy, Hoque, and Yilmazkuday (2024) found that the combination of geopolitical risk and global supply chain pressures drives up global inflation, with this effect being particularly pronounced in essential goods such as energy and food. This approach moves beyond the classical framework that evaluates the war economy solely through budget deficits or money supply. The conflict inflation and post COVID inflation frameworks developed by Proaño (2025) and Knicker, Gualdi, and Bouchaud (2025) similarly emphasize that a significant portion of recently observed inflationary pressures is related to distribution conflicts, supply shocks, and the deterioration of expectations, rather than a wage demand spiral. As energy, logistics, and insurance costs rise during times of war, the accelerated pass through of these costs to final prices by firms generates a cascading price pressure on food and agricultural products.

Significant strand of literature pertains to the effects of the war economy on food security. Abay, Breisinger, Glauber, Kurdi, Laborde, and Siddig (2023) highlight that the Russia and Ukraine war has induced price shocks, loss of access, and nutritional degradation, particularly in food-import-dependent countries. The same study demonstrates that the Middle

East and North Africa (MENA) region exhibits a specific vulnerability due to its high import dependency. In their computable general equilibrium analysis of 19 developing countries, Arndt et al. (2023) found that the war exacerbated both poverty and hunger through the channels of food, fuel, and fertilizer prices; furthermore, they observed that fuel and fertilizer prices predominantly disrupted agricultural systems, while food prices more severely impaired nutritional quality. Lin et al. (2023) indicate that under scenarios where the war intensifies, substantial declines in wheat trade, spikes in wheat prices, and severe deteriorations in purchasing-power-based food access occur. The review study by Ben Hassen and El Bilali (2022) also underscores the emergence of a multidimensional pressure on global food security via energy, fertilizer, grain, and logistics channels.

The war economy has become a determinant not only of price levels but also of market volatility and expectations management. By decomposing the impact of geopolitical risk indices on the volatility of commodity returns, Özdemir (2025) demonstrates that the threat of war and actual hostilities operate in the same direction but with varying intensities. Li (2025) posits that the relationship between geopolitical risk and food price inflation can be attenuated or amplified by institutional structure, economic cycles, and climate pressures. This body of literature reveals that an exclusive focus on supply deficits in agricultural markets is inadequate; prices are concurrently shaped by risk premiums, uncertainty, forward contracts, stocking behavior, and speculative expectations. Indeed, Countryman et al. (2025) show that Ukraine-sourced agricultural export contractions generate multilayered impacts on global production, consumption, and welfare, whereas the Grain Corridor established through the mediation of Turkey and the United Nations has played a mitigating role against price pressures.

In the war economy literature is the energy food fertilizer nexus. Quitzow et al. (2025) jointly examine the linkages between fertilizer supply security, energy transition, and geopolitical risk; they demonstrate that natural gas dependency in fertilizer production leaves agricultural systems exposed to all types of geopolitical shocks in energy markets. Vos et al. (2025) also state that shocks in global fertilizer markets engender asymmetric effects on price, trade, and application, noting that the tendency of farmers particularly in low and middle income countries to reduce fertilizer use could exert delayed pressures on production. The World Bank's

commodity outlook reports confirm that fertilizer prices reached historical peaks in 2022 and have remained above long term averages despite a partial softening post 2025. Consequently, the impact of the war economy on agriculture persists not only during the harvest period but also through input decisions carried over to the subsequent season.

The financial impacts of the war economy are particularly pronounced in developing countries. Surging CDS premiums, exchange rate volatility, external financing costs, and reserve pressures rapidly inflate the local currency prices of imported inputs, even if they do not directly increase agricultural production costs. In the case of Turkey, Oral, Çakıcı, Yıldız, and Alayoubi (2023) have demonstrated that the exchange rate, energy, and global factors play a significant role in determining food prices. The study by Akarsu et al. (2025), which decomposes the supply and demand components of inflation in Turkey, shows that supply-side factors have been decisive in the recent inflationary wave. The work of Türken and Yıldırım (2024) further reveals that food price shocks have second-round effects on core inflation. These findings suggest that war induced food shocks impact not only the agricultural sector but also overall price stability and monetary policy.

The resilience of food systems against sudden shocks, Huang et al. (2025) emphasize that pandemics, geopolitical conflicts, and extreme climate events strain food systems either simultaneously or sequentially; therefore, resilience must be addressed not solely through production, but across logistics, financing, storage, digital monitoring, and governance dimensions. Zhao et al. (2024) highlight that the preparation, response, recovery, and learning phases within agri food supply chains must be considered holistically; indicating the necessity for institutionalized resilience strategies rather than one off interventions. This approach is particularly valuable for economies like Turkey that frequently experience shocks; because the issue here is not the impact of a single war, but the cumulative pressure of successive crises.

By collectively analyzing the effects of COVID 19 and the Russia Ukraine war on the price volatility of wheat, sunflower oil, and corn in Turkey, Urak (2024) demonstrates that the combination of the pandemic and the war with exchange rate shocks magnifies the risks. Urak's (2025) more comprehensive study further asserts that the challenges in Turkish

agricultural markets cannot be explained solely by war or the pandemic; they can be interpreted more accurately when considered in tandem with energy market dynamics. This literature is highly significant as it dictates that food inflation and agricultural vulnerability in Turkey must be evaluated within the context of multiple shocks.

The war economy literature is increasingly focusing on the problem of the "spatial transmission of geopolitical risk. By analyzing the pressure exerted by Russia's invasion of Ukraine on South Africa's wheat supply and the necessity for trade diversification, Lim et al. (2024) show that conflict can alter import strategies even in geographically distant countries. This finding indicates that an Iran-centered regional conflict could rapidly affect Turkey not only due to border proximity but also via energy, insurance, port, transit, and expectations channels.

A prominent recent debate in the war economy literature is the opportunity cost of crises. During wartime, while some countries gain an export advantage due to higher commodity prices, importing countries can experience rapid welfare losses. In the Russia and Ukraine war, while oil and gas exporting nations experienced a certain degree of revenue growth, energy importing countries faced severe cost pressures. In this framework, Turkey's position exhibited a dual structure: on one hand, it assumed a geostrategic role in the Black Sea grain corridor and reaped certain benefits in tourism and transit logistics; on the other hand, it suffered substantial losses due to a high energy bill, fertilizer and feed costs, exchange rate pressure, and food inflation. Therefore, a war economy functions as a redistribution mechanism that simultaneously presents both risks and opportunities to each country; however, the direction of the net effect is determined by the country's structure of foreign dependency and its policy capacity. Rural sustainability literature also highlights the role of digital technologies in enhancing ecological literacy and environmentally responsible behavior in rural communities (Ozkan et al., 2020).

The literature points to four robust conclusions. First, wars now generate cost-push inflation on a global scale through strategic markets such as energy and grain. Second, supply chains that became fragile post-pandemic are rendered even more vulnerable by wars. Third, the issue of food security is tied not only to the physical supply quantity but also to price accessibility and purchasing power. Fourth, in countries like Turkey which

have high agricultural potential but are externally dependent on energy and certain inputs the impact of wars is often felt very rapidly and severely, even if they are not directly engaged in the conflict. For this reason, understanding the potential effects of the Iran US and Israel conflict on Turkish agriculture requires relying not merely on the current news flow, but on the theoretical and empirical literature accumulated over the last six years.

LESSONS LEARNED FROM THE PANDEMIC

The COVID 19 pandemic unequivocally demonstrated the extreme fragility of supply chains built upon the just in time logic of the modern global economy. In the pre-pandemic era, objectives such as efficiency, cost minimization, and inventory reduction were widely regarded as indicators of productivity and operational success. However, the pandemic revealed that these structures had been established at the expense of resilience. Food and agricultural supply chains were particularly critical in this process, as disruptions in these sectors affected not only corporate profitability but also directly influenced household nutrition and social stability.

In their digital twin-based analysis of food retail chains in Germany, Burgos and Ivanov (2021) demonstrate that the most severe impacts of the pandemic did not arise from a complete interruption of supply or transportation, but rather from the simultaneous occurrence of sudden demand spikes and supplier shutdowns. This finding is significant because it suggests that supply chain vulnerability does not stem solely from the closure of physical transportation routes, but also from concurrent behavioral and operational disruptions. During the pandemic, consumer panic buying, stockpiling behavior, and sudden shifts in product demand rapidly rendered ordering and inventory algorithms previously considered optimal under normal conditions ineffective.

Barman, Das, and De (2021) classify the fundamental problems faced by food supply chains during the pandemic as demand contraction, production shutdowns, labor constraints, logistical barriers, and financing difficulties. They particularly emphasize that restrictive lockdown measures complicated the availability of agricultural labor, harvesting operations, and the timely delivery of products to retail markets. This situation highlighted that food supply chains, unlike many other sectors, operate within much

narrower decision windows due to the combined effects of seasonality and perishability. In many countries, agricultural production continued; nevertheless, significant economic losses occurred because products could not be processed or transported to markets in a timely manner.

A key finding within the pandemic literature is that different echelons of supply chains are exposed to the same shock to varying degrees. Long, multi-layered, and cross-border supply chains tended to experience more severe disruptions, whereas short supply chains, direct sales channels, and local market networks often displayed greater resilience. Durant et al. (2023) demonstrate that farmers engaged in direct-to-consumer sales in California maintained higher levels of resilience during the pandemic through the use of online sales platforms, product diversification, and direct consumer engagement. This finding suggests that resilience is influenced not only by economies of scale but also by market access structures and institutional flexibility.

Mishra, Singh, and Subramanian (2022) conceptualize the disruptions caused by the pandemic in agri-food supply chains and propose a resilience framework centered on the phases of “preparedness, response, recovery, and learning.” Their study treats crisis management not as a one-time emergency intervention but as a continuous institutional process requiring governance capacity and organizational learning. Similarly, Modgil, Singh, and Hannibal (2022) emphasize that artificial intelligence and data visibility tools can significantly enhance supply chain resilience during sudden shocks such as pandemics. Real-time data systems, demand forecasting models, route optimization tools, and supplier diversification strategies can substantially reduce delays and waste in food supply chains.

Another critical lesson from the pandemic is that food security cannot be understood solely in terms of the question, Is the product available? Supply chain disruptions frequently created regional or temporary access problems rather than absolute physical shortages. While certain products disappeared from supermarket shelves in urban areas, producers in rural regions simultaneously struggled to sell their products. This asymmetric structure highlighted the importance of logistical integration and efficient information flows within food systems. Moreover, slowdowns at border crossings, container shortages, port congestion, and rising transportation

costs demonstrated that logistics should be treated as a strategic sector for ensuring the resilience of global food trade.

For Turkey, the pandemic experience is instructive for several reasons. First, disruptions in the mobility of seasonal agricultural workers negatively affected harvesting and maintenance processes (Er and Gürbüz, 2022). Second, increases in international transportation and freight costs raised the prices of imported feed, fertilizer, and certain agricultural raw materials. Third, exchange rate volatility amplified the transmission of global price shocks to domestic markets. Fourth, consumer perceptions of food inflation intensified, influencing the composition of demand. The pandemic therefore revitalized debates surrounding food self-sufficiency in Turkey's agricultural system while simultaneously revealing the critical importance of externally dependent components of agricultural production, such as energy, fertilizer, seeds, feed, and logistics.

Consequently, the pandemic left the global economy in a structurally fragile position with respect to subsequent war-induced shocks. Issues such as inventory management, diversified supplier networks, the strengthening of short supply chains, digital visibility, strategic reserves, and logistical flexibility gained increasing importance in the post-pandemic period. However, the Russia–Ukraine war erupted before these resilience strategies could be fully institutionalized. Therefore, when evaluating the potential impacts of a new Iran-centered conflict, it is essential to consider the legacy of the pandemic as the baseline condition shaping current vulnerabilities.

IMPACTS OF THE RUSSIA UKRAINE WAR ON THE GLOBAL AGRICULTURAL SYSTEM

The Russia and Ukraine war generated a multidimensional shock to the global economy, operating simultaneously through energy, food, fertilizer, financial markets, and geopolitical expectations. To understand the war's impact on the world economy, it is first necessary to examine the position of the two countries in global agricultural and energy markets. In the pre-war period, Russia and Ukraine together accounted for nearly one-third of global wheat exports, the majority of sunflower oil exports, and played a critical role in global corn trade. Russia is also one of the key actors in natural gas and fertilizer production. Therefore, when the war began, the

issue was not merely a conflict between two countries but a supply and logistics shock occurring at the core of global commodity flows.

Abay et al. (2023) show that the war led to higher food prices and reduced access to food, particularly in import-dependent countries. Lin et al. (2023) project a sharp decline in wheat trade and a significant increase in food insecurity under adverse scenarios. Arndt et al. (2023) demonstrate that in developing countries, the war simultaneously intensified poverty and hunger through rising food, fuel, and fertilizer prices. When these studies are considered together, it becomes clear that the war represented more than a conventional supply shock. Rising prices increased import bills, reduced real incomes, strained social protection systems, and generated welfare losses that in some cases threatened political stability.

Energy markets were the first and fastest to react to the war. Aizenman et al. (2024) show that war-related news generated high-frequency price movements in natural gas markets. World Bank commodity reports similarly indicate that energy prices rose sharply in 2022, creating cost pressures on a scale comparable to the oil shocks of the 1970s. This surge in energy prices was particularly critical for agriculture for two reasons. First, it directly increased production costs through higher diesel and electricity prices. Second, because natural gas is the primary input in fertilizer production, it triggered a sharp increase in fertilizer prices. Consequently, the energy shock translated into a dual cost pressure on agricultural production.

The fertilizer market produced one of the most significant, though initially less visible, consequences of the war. IFPRI analyses and World Bank data indicate that fertilizer prices increased dramatically after 2022, and this increase was not merely a temporary supply disruption. Russia and Belarus hold a substantial share of global supply for several key fertilizer types, which amplified the impact of both the war and the sanctions regime. Vos et al. (2025) emphasize that fertilizer shocks generate delayed global effects on farmer behavior, application rates, and ultimately the following season's production levels. From an agricultural economics perspective, this is a critical point: the effects of the war may be observed not only in the harvest of the war year but also in subsequent production seasons.

The logistical dimension of the war is equally significant. Disruptions in Black Sea ports, rising insurance costs, vessel risk premiums, and

increasing freight rates deeply affected global grain trade. Countryman et al. (2025) show that export declines originating from Ukraine generated measurable welfare losses in the global economy, while the Black Sea Grain Initiative partially alleviated these pressures. According to IFPRI, the shipment of approximately 33 million tons of grain and agricultural products from Ukrainian ports during the corridor's operation contributed to a downward adjustment in international prices. However, the fragile nature of the agreement and Russia's eventual withdrawal from it demonstrated how dependent global markets had become on geopolitical negotiations.

From a broader perspective, the war produced two major macroeconomic consequences. First, inflationary pressures became widespread. Rising energy and food prices forced central banks to raise interest rates, tightening global financial conditions. Second, the war generated downward pressure on economic growth. For energy-importing countries in particular, higher energy import bills worsened current account balances, reduced household consumption, and increased industrial production costs. As a result, the war simultaneously created inflationary pressures and slower growth, producing a stagflation-like macroeconomic environment.

For the global agricultural and food system, one of the most enduring consequences of the war has been the renewed emphasis on strategic diversification. Many countries recognized the risks associated with relying heavily on a single region or supplier. As a result, policies promoting alternative supply sources, strategic reserves, and domestic production incentives gained prominence. This trend has been observed not only in importing countries but also among exporters. While Russia used export restrictions and trade policy as geopolitical tools, other producing countries responded to higher prices by adjusting cropping patterns and expanding production. Consequently, the war initiated a gradual transformation in global agricultural geography through the redistribution of supply.

Nevertheless, the war also produced certain winners. Some energy-exporting countries benefited from increased revenues due to higher energy prices, while alternative grain and oilseed exporters gained market share in several regions. However, from the perspective of global welfare, the overall impact remained negative. The groups most affected by rising prices were

low-income importing countries and vulnerable households. Food insecurity became increasingly visible, particularly in the Middle East, North Africa, and Sub-Saharan Africa.

By the fourth year of the Russia and Ukraine war, the fundamental lesson for the global economy has become clear: energy, food, fertilizer, and logistics markets are deeply interconnected. A geopolitical disruption in one of these sectors rapidly transmits shocks to the others. Therefore, when assessing the potential impacts of a new Iran centered conflict, it is insufficient to focus solely on oil prices. LNG markets, fertilizer inputs, maritime insurance costs, freight rates, imported agricultural inputs, Exchange rate volatility, and food price pass through effects must all be analyzed together within an integrated framework.

POTENTIAL IMPACTS OF THE GULF CONFLICT ON TURKISH AGRICULTURE

The scenario analyzed in this section concerns the Iran US and Israel conflict, which began on February 28, 2026, and had reached its 17th day as of March 16, 2026. According to international news sources, security risks surrounding the Strait of Hormuz during the first two weeks of the conflict generated significant pressure on energy and transportation markets. A sudden spike in oil prices, disruptions in LNG flows, and particularly price increases in nitrogen based fertilizer inputs quickly became prominent concerns. The U.S. Energy Information Administration notes that the Strait of Hormuz is one of the world's most critical energy chokepoints and that approximately one-fifth of global LNG trade passes through this route. In recent days, both international media outlets and fertilizer industry representatives have warned that disruptions in Gulf sourced ammonia, urea, and other nitrogen-based products could once again push global food costs upward.

To understand the potential effects of an Iran centered conflict on Turkish agriculture, it is first necessary to examine what Turkey gained and lost during the Russia and Ukraine war. Turkey achieved three notable gains during that conflict. First, it enhanced its strategic importance by assuming a mediating role in the Black Sea Grain Corridor diplomacy. Second, it gained greater flexibility in regional logistics and trade networks, enabling some

exporters to discover new markets and transit opportunities. Third, the war elevated agriculture and food security to a more prominent position on the national policy agenda, reinforcing the importance of long term strategic planning.

However, the losses were considerably more structural: a rising energy import bill, sharp increases in fertilizer and feed costs, strong exchange-rate pass-through effects, persistent food inflation, and declining producer profitability. The common conclusion emerging from the studies of Oral et al. (2023), Urak (2024; 2025), and recent research on food inflation in Turkey is that war-induced shocks are rapidly transmitted to domestic food prices through exchange rate movements and energy costs.

In certain respects, the Iran US and Israel conflict poses greater risks than the Russia and Ukraine war because of its proximity to Turkey's energy and logistics geography. While the Russia and Ukraine war primarily affected Turkey through the Black Sea and grain fertilizer trade corridors, an Iran centered conflict has the potential to generate direct impacts through oil markets, natural gas flows, LNG supply chains, maritime insurance costs, and Gulf shipping routes. Persistent security risks in the Strait of Hormuz could therefore influence not only crude oil markets but also natural gas and ammonia-based inputs used in fertilizer production.

Accordingly, the short term vulnerabilities of Turkish agriculture can be grouped into four main categories: rising energy costs, increases in fertilizer and chemical input prices, higher feed and logistics costs, and financial expectations combined with Exchange rate volatility.

In the short term, the initial pressure will emerge through diesel and electricity costs. Irrigation, mechanization, greenhouse heating, cold chain logistics, and agricultural transportation are all energy intensive activities. A sudden increase in oil prices within a short period of time can rapidly escalate cost pressures, particularly in vegetable and fruit production, greenhouse cultivation, and livestock farming. A similar cost shock occurred during the Russia and Ukraine war; however, at that time Turkey was able to partially reorganize its Black Sea logistics networks. In an Iran centered conflict, the energy shock could be more direct and widespread. If producers face sudden increases in diesel prices, irrigation electricity costs, and transportation expenses especially ahead of the spring and summer

production seasons they may respond by reducing planting areas or scaling back input use.

The second short term pressure will arise in fertilizer markets. Recent reports in Barron's and The Guardian indicate that urea prices increased sharply during the first two weeks following the outbreak of the conflict, highlighting the risk of disruptions in Gulf sourced nitrogen fertilizer supply. Warnings from the CEO of Yara also suggest that a prolonged conflict could have serious implications for fertilizer availability and, consequently, global food production. Given Turkey's strong dependence on imported fertilizers and the central role of natural gas in fertilizer production costs, such a shock could quickly influence farmers' input decisions. As observed during the Russia and Ukraine war, producers may respond to high fertilizer prices by reducing application rates, delaying fertilizer use, or applying lower quantities. While this behavior may not cause an immediate collapse in production within the same season, it can create delayed pressures on yields, product quality, and cost structures.

The third short-term risk concerns feed and livestock costs. Turkey's livestock sector is highly dependent on energy prices, imported feed inputs, and transportation costs. Increases in oil prices and freight rates are quickly transmitted to feed prices, which in turn affect milk and meat production costs. In sectors such as dairy farming, where profit margins are already narrow, producers may face increasing pressure to operate at a loss. Over the medium term, this situation may evolve into structural challenges, including the premature slaughter of breeding animals or the downsizing of livestock enterprises. Similar dynamics were observed during the Russia and Ukraine war, when rising feed and energy costs placed severe pressure on the livestock sector; the current conflict could reinforce these pressures once again.

The fourth short term risk relates to logistics and maritime insurance costs. Rising war related risks in the Gulf region and the Eastern Mediterranean may increase maritime insurance premiums, lengthen transportation routes, and extend delivery times at ports. Turkey's agricultural foreign trade does not involve only grain imports; fertilizers, feed additives, chemicals, and packaging inputs are also affected by such disruptions. Container and freight markets, which have remained fragile since the pandemic, tend to become more expensive during periods of

heightened geopolitical risk. Consequently, the short-term impacts may manifest not only as higher import costs but also as delayed supply, disrupted cash flows, and increased working capital requirements.

A fifth short-term transmission channel involves expectations and exchange rate dynamics. As an energy importing economy, Turkey may face additional pressure on its foreign trade balance and current account during a prolonged conflict, potentially intensifying exchange rate volatility and increasing financing costs. Because exchange rate pass-through is relatively high in Turkey, increases in imported input prices are quickly reflected in farm-level costs and subsequently in consumer food prices. As demonstrated by Türken and Yıldırım (2024), food price shocks can generate second-round effects on core inflation. Consequently, an Iran centered conflict could disrupt not only agricultural production costs but also broader macroeconomic stability. A renewed surge in food inflation may prompt tighter monetary policy, which in turn would raise the cost of agricultural credit and financing. Long term impacts are more dangerous than short term price shocks because they alter behavior, investment decisions, and the structure of production.

The first long term impact may be a permanent rationalization of input use accompanied by a decline in productivity. If farmers face persistently high fertilizer and energy costs for several months, the tendency to withdraw from production particularly on marginal land may intensify. Producers may shift toward crops requiring fewer inputs or abandon certain activities altogether. This process would not immediately reduce Turkey's total production capacity; rather, it would gradually erode it over several production seasons.

The second long term impact concerns changes in cropping patterns. Crops that depend heavily on nitrogen fertilizers and intensive irrigation may become relatively less competitive. As farmers shift toward crops requiring fewer inputs, the supply balance of certain strategic commodities in the domestic market may deteriorate. When combined with climate conditions and agricultural support policies, these shifts could also alter regional specialization patterns. For instance, fodder crops, maize, industrial tomatoes, greenhouse production, and certain energy-intensive agricultural systems may face greater pressure under such conditions.

The third long term effect relates to declining investment incentives in agriculture. A prolonged conflict reduces predictability in input markets. In an environment of heightened uncertainty, farmers may postpone or avoid investments in modern irrigation systems, advanced machinery, storage facilities, or livestock production. This situation can significantly limit productivity growth in the agricultural sector. Urak's (2025) analysis of Turkey indirectly demonstrates that the relationship between energy market dynamics and agricultural market volatility also influences the broader investment climate.

The fourth long term impact may involve a reorientation in the structure of agricultural foreign trade. During the Russia and Ukraine war, Turkey used various trade policy instruments to stabilize its domestic market in certain commodities. However, in the case of a prolonged Iran centered conflict, the logistical geography could become considerably more complex. Gulf countries represent important export markets for Turkey's agro food industry. If demand contraction, payment risks, or logistical disruptions occur in these markets, exporting firms may be forced to seek alternative destinations. In the short term, products redirected to the domestic market may temporarily suppress prices. Nevertheless, declining export revenues and uncertainty in external demand may complicate firms' capacity planning and investment decisions.

The fifth long-term impact concerns the persistence of food inflation. Food prices in Turkey are already characterized by high volatility, and a new conflict generating repeated energy and Exchange rate shocks could delay the normalization of prices. Under such circumstances, consumers may increasingly shift toward cheaper and lower quality food products, while producers may adopt cost-avoidance strategies that reduce input use or quality standards. From a broader perspective, this outcome may extend beyond agricultural economics into the realm of social policy, affecting both nutritional quality and food accessibility.

The sixth long term effect involves the reshaping of debates surrounding strategic autonomy. The Russia and Ukraine war demonstrated Turkey's capacity for logistical diplomacy and regional mediation in agricultural trade. At the same time, however, it highlighted the economic costs of dependency on imported energy and fertilizers. If the Iran US and Israel conflict persists, three strategic priorities are likely to become

increasingly prominent for Turkey: (i) strengthening fertilizer and energy supply security; (ii) diversifying supply sources for oilseeds and feed raw materials; and (iii) promoting water-efficient and low-input agricultural production models. The analytical framework proposed by Quitzow et al. (2025), which examines the relationship between fertilizer supply security and geopolitical risk, is particularly instructive in this context.

The seventh long term effect concerns the growing visibility of weaknesses in agricultural insurance and risk management systems. During wartime, farmers are exposed not only to climate risks such as drought or frost but also to geopolitical price shocks that threaten farm income. For this reason, crop insurance alone is insufficient. A comprehensive risk management system should include income insurance, targeted input subsidies, strategic reserves, and credit restructuring mechanisms. If an Iran centered conflict persists and energy prices remain elevated, the existing agricultural support structure may prove insufficient to offset the rising cost pressures faced by producers.

The eighth long term impact stems from the dual nature of Turkey's regional geopolitical position, which presents both opportunities and risks. Due to its geographical location, Turkey has the potential to act as a transit country, mediator, and alternative logistics hub during regional crises. This role generated certain diplomatic and economic advantages during the Russia and Ukraine war. However, the same geographical position could also translate into higher geopolitical risk premiums, increased border security pressures, transportation disruptions, and energy price shocks in the context of an Iran-centered conflict. Therefore, the most important lesson Turkey has drawn from the Russia and Ukraine experience is that geopolitical advantage alone is insufficient without structural agricultural resilience.

Within this framework, policy recommendations should be considered at five levels. First, short term emergency plans should be developed to strengthen fertilizer and energy supply security. Second, the Turkish Grain Board and related institutions should enhance their strategic stock management and market monitoring capacities. Third, targeted support measures should be implemented to alleviate the financial burden on producers, particularly in key cost components such as diesel, electricity, irrigation, and fertilizers. Fourth, feed crop incentives and temporary support

programs should be introduced to reduce feed costs in the livestock sector. Finally, in the medium term, the transition toward agricultural production systems characterized by lower input dependency, greater water efficiency, and greater reliance on renewable energy should be accelerated.

The central lesson of the Russia and Ukraine war is that temporary crisis responses are insufficient. Without reducing structural dependencies, each new geopolitical shock risks returning with greater intensity and amplifying the damage caused by previous crises.

RESULTS AND DISCUSSION

This study aimed to evaluate, within an integrated framework, the effects of successive global crises in recent years the pandemic, the Russia and Ukraine war, and the Iran US and Israel conflict on the agricultural economy. The analysis shows that modern agricultural systems have become increasingly dependent on global networks of energy, fertilizer, finance, and logistics, and that geopolitical shocks are therefore no longer confined to conflict zones alone. In particular, the supply chain vulnerabilities that emerged in the post-pandemic period, when combined with the Russia–Ukraine war, have once again brought the resilience of global food systems to the forefront of academic and policy debate. In this context, understanding the potential effects of a new Iran centered conflict requires a joint assessment of both the pandemic experience and the economic consequences of the Russia and Ukraine war.

The pandemic revealed that the apparently efficient just in time supply structures of global food systems were, in fact, characterized by low resilience. Simultaneous disruptions in production, logistics, and retail created short-lived yet intense price volatility in food markets. In the post-pandemic period, many countries began to develop policies aimed at expanding strategic food reserves, promoting local production, and creating alternative supply channels. However, before these measures could be fully institutionalized, the Russia and Ukraine war broke out, once again destabilizing the global agricultural system through the interconnected channels of energy, food, and fertilizer.

Three main transmission mechanisms stand out when examining the effects of the Russia and Ukraine war on the global economy. The first is

energy markets. Rising oil and natural gas prices directly increased agricultural production costs. The second is fertilizer markets. Higher natural gas prices, together with supply constraints in certain producer countries, led to historically significant spikes in fertilizer prices. The third is logistics and trade. The closure of Black Sea ports, rising insurance costs, and increasing freight rates severely disrupted global grain trade. These developments intensified price shocks and food insecurity risks, especially in countries heavily dependent on food imports.

From Turkey's perspective, the Russia and Ukraine war generated both opportunities and substantial costs. Turkey assumed a diplomatic role in the establishment of the Black Sea Grain Corridor and, in doing so, strengthened its potential as a regional logistics hub. At the same time, however, the war induced increase in energy prices, fertilizer costs, and exchange-rate pressures created significant cost shocks for Turkish agriculture. Since critical agricultural inputs such as diesel, electricity, fertilizer, and feed are heavily import dependent, global price shocks were rapidly transmitted to the domestic market. This became one of the key factors behind persistently high food inflation.

When assessing the potential effects of the current conflict involving Iran, a risk profile distinct from that of the Russia–Ukraine war emerges. At the center of this conflict lie energy markets, particularly oil and LNG trade through the Strait of Hormuz. The fact that a substantial share of global oil trade passes through this route indicates that regional security risks can generate rapid and powerful effects on energy prices. Rising energy prices, in turn, affect the agricultural sector through both direct and indirect channels.

In the short term, the most significant risks facing Turkish agriculture include rising energy costs, higher prices for fertilizer and chemical inputs, increasing feed costs, and higher logistics expenses. In particular, sudden increases in diesel prices may reduce producer profitability by raising irrigation and mechanization costs. Likewise, higher fertilizer prices may alter farmers' input use decisions. While lower fertilizer use may temporarily reduce production costs, it is likely to have adverse effects on productivity in the medium and long term.

From the perspective of the livestock sector, feed prices and energy costs are of critical importance. The fact that a substantial share of feed raw

materials is imported means that international price increases are transmitted rapidly to the domestic market. This can intensify cost pressures in milk and meat production and increase the risk of producer exit from the sector. Consequently, prolonged increases in energy prices could generate structural contraction in livestock production.

In the long run, the effects of an Iran centered war on Turkish agriculture may become more structural in nature. These may include changes in cropping patterns, declining willingness to invest in agriculture, a permanent reduction in input use, and increasingly persistent food inflation. In particular, if fertilizer and energy prices remain elevated for an extended period, farmers may shift toward crops that require fewer inputs. This, in turn, may disrupt the supply balance of certain strategic commodities. At the same time, Turkey's geographical position also offers certain opportunities. Located between Europe and the Middle East, Turkey occupies an important logistical position and may play a role in the emergence of alternative trade routes during periods of crisis. The diplomacy surrounding the grain corridor during the Russia and Ukraine war provides a concrete example of this role. However, for such geopolitical advantages to translate into economic gains, the agricultural sector itself must become structurally more resilient.

At this point, three strategic priorities stand out for policymakers. The first is reducing dependence on imported inputs. Expanding domestic production capacity, particularly in fertilizer and energy, could mitigate the effects of agricultural cost shocks. The second is the promotion of technological investments that improve productivity in agriculture. Digital agriculture, precision farming, and water efficient technologies present important opportunities in this regard. The third is strengthening risk-management tools. Instruments such as agricultural insurance, income insurance, and strategic food reserves can protect producer and consumer welfare during periods of crisis.

In conclusion, this study demonstrates that the effects of geopolitical conflicts on modern agricultural systems are becoming increasingly pronounced. The Russia and Ukraine war exposed the fragility of global food systems, while a new Iran centered conflict suggests that these vulnerabilities may once again be put to the test. For Turkey, the fundamental problem lies less in war itself than in the structural dependencies of its agricultural sector. As long as external dependence on

critical inputs such as energy, fertilizer, and feed continues, global geopolitical shocks will be felt rapidly and forcefully in the domestic market. For this reason, the primary goal of agricultural policy should not be limited to increasing production; it should also encompass strengthening agricultural resilience and ensuring strategic food security.

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The Economic Cost of Illness of the Principal Farm Operators in Kogi State, Nigeria

**Theophilus Miebi Gbigbi^{1*}
Joseph. Adams Ojogbane²**

¹Delta State University, Faculty of Agriculture, Department of Agricultural Economics, Abraka, Nigeria
^{*}(gbigbitheophilusmiebi@yahoo.com)

²Department of Agricultural Education, School of Vocational Education, Federal College of Education (Technical), Asaba.

ABSTRACT

Farm output of farmers has been declining over the years and the consequences were attributed to illness but the effect on output and profitability has not been investigated to guide policymakers hence this study examines the economic cost of illness of the principal farm operators. A multistage random sampling technique was used to select 90 respondents for the study. The study used descriptive and inferential statistics to achieve the objectives of the study. The result of the cost and return analysis revealed that the principal farm operator was running at a loss in the farm business with a negative net farm income (NFI) of ₦-989,113, gross margin (GM) of ₦-662,278, and BCR of 0.82. The output of the farm operator was significantly influenced by health expenditure, proximity to the nearest health center, number of times sick, farm size, cost of labour, cost of inputs used, types of crop grown, and weather conditions. The result of the illness type shows that malaria is the predominant disease. The t-test result showed that there was a significant difference in farm output, farm size, and income before and during sickness. The government and other stakeholders in the farming and health industries should provide medical care for the principal farmer at an affordable cost for sustainable production.

Keywords: illness, farm operator, output, profitability

I. INTRODUCTION

Malaria, yellow fever, cholera, typhoid fever, HIV/AIDS, hepatitis B, musculoskeletal disorders, and other diseases are common in Nigerian farming communities. Agricultural productivity has suffered significant losses as a result of these viral illnesses. These diseases cause farmers to not completely utilize all of the inputs at their disposal, resulting in decreased physical performance and a negative influence on farm profit levels. Farmers who are sick are unable to work on the farm or must discontinue their farming activity. Additionally, funds that could have been utilized to purchase farm inputs, upgrade equipment, or hire tractors and labourers are instead allocated for treatment, resulting in low output (Quintussi et al 2015).

Furthermore, the disease has an impact on agriculture because it reduces the quality and quantity of labour, which is diminished when a disease-infected individual becomes ill and eventually dies. Other members of the household will divert production time to care for the sick person (Cohen and Venter, 2020). Similarly, the availability of disposable income will be affected because, during times of illness, household financial resources may be diverted to pay for medical treatment and, eventually, to meet financial costs that would otherwise be used for other purposes (Mahumud et al 2017, Chandler et al 2015). Agriculture-focused research has highlighted the negative impact of poor health on the well-being of farming households,

which has an impact on overall economic development. According to their report, the ultimate effect of ill health is a decline in household income and food security.

In addition, endemic and parasitological diseases were investigated for their negative health and economic effects. Gbigbi (2020) discovered a negative relationship between malaria and income. It implies that bettering one's health will not only improve one's life but will also promote rapid economic growth on its own. Through increased physical and mental capacities, good health improves a person's productivity and effectiveness at work. Miller (2016) also found a link between sound health and labour productivity for both trained and untrained workers.

However, considerable work remains to be done to prevent disease and promote the health of those who work in agriculture. There is a paucity of understanding about how many people are adversely affected by illness, particularly in the long run. The disease reporting system is still terribly inadequate, making it nearly impossible to precisely follow trends and estimate accurate numbers of persons with illnesses, resulting in low agricultural productivity.

Farmers' productivity is diminished in developing countries due to poor health, which reduces their output and revenue (Fink and Masiye 2015, Kimani et al 2016). Diseases were studied for their effects on production, productivity, and physical ability (Asenso-Okyere et al 2011, Audibert and Etard 2003, Nur and Mahran 1988 and Idris et al 2015).

Despite this finding, past research has failed to take a comprehensive approach to the issue of farmer health and its impact on output. However, the studies that are now available are too old to advise policy direction at this time. As a result, this research was conducted to determine the economic cost of illness among the principal farm operators.

II. MATERIALS AND METHOD

Area of Study

This study was conducted in Okene local government area. It is surrounded to the north by Adavi LGA, to the south by Edo State, to the west by Ondo State, and the east by Ajaokuta LGA. It is located at latitude 7^o33'N and longitude 6^o14'E. It has a land area of 328 km² and a population of 320,260 (NPC 2006). The people of Okene LGA are predominantly farmers cultivating sweet potato, yam, maize, vegetables, cassava, sesame, sorghum, and groundnut.

Sampling Procedure/Data Collection

A multistage sampling procedure was used for this study. In the first stage, 6 communities were randomly selected that make up the local government. In the second stage, 15 smallholder farmers were randomly selected from each of the 6 selected communities. This gave a sample size of 90 smallholder farmers that was used for the study. The data for this study was obtained from

the primary source. The tool for collecting the data was a well-structured questionnaire.

Method of Data Analysis

Descriptive statistics and inferential statistics were used for the analysis of data.

Model specification:

Profit of the Respondents

This is specified as:

$$\Pi = TR - TC \dots\dots\dots(1)$$

$$TR = PQ \dots\dots\dots(2)$$

Where:

Π = Total profit (₦)

TR = Total revenue (₦)

TC = Total cost (₦)

P = Unit price of output (₦)

Q = Total quantity of output (kg)

Determinants of the Output of the Respondents

$$Y = \text{HEXP} + \text{TRANS} + \text{NOTS} + \text{FARMS} + \text{COLAB} + \text{INPU} + \text{TOCG} + \text{WCOND}$$

where:

Y = output (₦)

HEXP = health expenditure (₦)

TRANS = Transportation (₦)

NOTS = Number of times sick (number)

FARMS = Farm size (ha)

COLAB = Cost of labour (₦)

INPU = Inputs used (₦)

TOCG = Type of crop is grown (improved varieties=1, otherwise=0)

WCOND = Weather conditions. (yes=1, otherwise=0)

e_i = error term

b_0 = intercept

b_1 - b_8 = estimated coefficients

III. RESULTS

Cost and Return of the Farm Operators

This shows the average annual costs and returns of the principal farm operator. The result in Table 1 showed annual total revenue of ₦4,385,500 and a total cost of ₦5,374,613. The result also showed that the net return and gross margin from arable crop farming in the area were ₦-989,113 and ₦-662,278 and respectively. The result revealed that drugs and prevention costs

accounted for 29.4% of the total cost of production, this was followed by the cost of labour which accounted for (8.1%), medical consultancy 7.6%, cost of fertilizer (6.7%), cost of planting materials (5.8%), agro-chemical (5.5%) and other variable cost components such as transportation, feeding, wage rate, bags/sacks, processing and miscellaneous accounted for 30.8% of the variables. Among the fixed cost, land accounted for 4.8% while the cost of farm tools accounted for 1.2%. The result of the cost and return shows that variable cost accounted for 94% while fixed cost accounted for 6% of the total cost of production by arable crop farming. The benefit-cost ratio (BCR) of 0.82 showed that an arable crop farmer losses ₦0.82 kobo for each naira invested since the BCR is less than one. This shows that arable crop farming is not profitable due to the ill health of the principal farm operator.

Table 1: Cost and Return of the Farm Operators

| Cost / Return Item | ₦ | Percentages |
|--------------------------------|-----------|--------------------|
| Revenue | 4385500 | |
| Variable Cost | | |
| Drugs and herbs | 1013200 | 18.9 |
| Medical consultancy | 408038 | 7.6 |
| Transportation | 280600 | 5.2 |
| Feeding | 231900 | 4.3 |
| The Wage rate of sick a person | 210038 | 3.9 |
| Wage rate of caretaker | 128472 | 2.4 |
| Prevention cost | 563000 | 10.5 |
| Planting materials | 314280 | 5.8 |
| Fertilizers | 360200 | 6.7 |
| Agrochemicals | 297100 | 5.5 |
| Labour | 434450 | 8.1 |
| Bags/sacks | 250750 | 4.7 |
| Processing | 237750 | 4.4 |
| Miscellaneous | 318000 | 5.9 |
| Total variable cost (TVC) | 5,047,778 | |
| Fixed Cost | | |
| Land depreciation | 260010 | 4.8 |
| Implement depreciation | 66825 | 1.2 |
| Total fixed cost | 326,835 | |
| Total Cost | 5,374,613 | |
| Net farm income | -989,113 | |
| Gross margin | -662,278 | |
| BCR | 0.82 | |

Determinants of the Output of the Farm Operators

The double log functional form was chosen as the lead equation because it best agrees with a priori expectations about the signs and magnitudes of estimates. The double log functional form has an F-value of 31.22 and R2 of 0.6726 which showed that 67.3% of the dependent variable is being elucidated by the explanatory variables while 32.7% is unexplained due to random error (Table 2).

Table 2: Determinants of the Output of the Farm Operators

| Variables | Coefficient | Standard error | t-value |
|----------------------|--------------------|-----------------------|----------------|
| Health expenditure | -0.1905763 | 0.0617683 | -3.09** |
| Transportation | -0.3029761 | 0.0361359 | -8.38*** |
| Number of times sick | -0.0723443 | 0.0088155 | -8.21*** |
| Farm size | 0.3979065 | 0.086065 | 4.62*** |
| Cost of labour | -2.705741 | 1.026909 | -2.63** |
| Cost of Inputs used | -0.0309817 | 0.0102924 | -3.01*** |
| Type of crop grown | 0.0233347 | 0.0100134 | 2.33** |
| Weather condition | -0.1625887 | 0.0628078 | -2.59** |
| Constant | 3.707 | 1.323066 | 2.80** |
| R2 | 0.6726 | | |
| F-ratio | 31.22 | | |

*** Significant at 0.01 level of significance ** Significant at 0.05 level

Prevalent Health Challenges of the Principal Farm Operator

The result as presented in Table 3 shows that 81 respondents represented by 90.0% had malaria, this was closely followed by 46 respondents represented by 51.1% having typhoid. About 37.8% representing 34 respondents had the combined effect of malaria and typhoid, and 22 respondents representing 24.4% had malaria and diarrhea. About 12.2% had typhoid and diarrhea. The result reviewed further than 20.0% representing 18 respondents had diarrhea. Similarly, another 4.4% representing 4 respondents had combined illnesses of malaria, diarrhea, and typhoid respectively.

Table 3: Distribution of Prevalent Health Challenges

| Health challenges | Frequency | Percentage |
|-------------------------------|------------------|-------------------|
| Malaria only | 88 | 98.0 |
| Diarrhea only | 24 | 26.7 |
| Typhoid only | 56 | 62.2 |
| Malaria and Diarrhea | 30 | 33.3 |
| Malaria and Typhoid | 54 | 60.0 |
| Typhoid and Diarrhea | 16 | 17.8 |
| Malaria, Diarrhea and Typhoid | 6 | 6.7 |
| Total | 274 | 100.0 |

Multiple responses

Effects of the Economic Cost of Illness of the Farm Operator

From Table 4, the respondents agreed that they were able to increase their farm output through farm expansion and the employment of more hands to assist with their farm business operations before the illness. This is symbolized by the means of 3.578. But during the health disorder output dropped drastically with a mean of 1.811. In terms of the farm size, the respondents also affirm that before health challenges, they had the opportunity to acquire more land for farming with a mean of 3.422 as against a mean of 1.578 during incapacitation as a result of sickness. The respondents have agreed to an improvement in income before ailment with a mean of 3.589 and 1.889 during ailment respectively.

Table 4: Effects of the Economic Cost of Illness

| Variables | Before | Std. | During | Std. |
|------------------|---------------|------------------|---------------|------------------|
| | mean | deviation | mean | deviation |
| Output | 3.578 | 0.687 | 1.811 | 0.898 |
| Farm size | 3.422 | 0.653 | 1.578 | 0.719 |
| Income | 3.589 | 0.538 | 1.889 | 0.841 |

The mean differences in output, farm size, and income indicated that there had been an inverse relationship with the ailment of the farmers. The paired test all obtained a p-value of 0.000 which is less than 5%.

Table 5: Paired Sample Results Effects of the Economic Cost of Illness

| | Variables | Mean | Std. | Std. | T | Sig. |
|--------|-----------------------------|-------------|------------------|--------------|----------|-------------|
| | | | deviation | error | | |
| Pair 1 | Before and during output | 1.767 | 1.142 | 0.1204 | 14.674 | 0.000 |
| Pair 2 | Before and during farm size | 1.844 | 1.012 | 0.107 | 17.227 | 0.000 |
| Pair 3 | Before and during income | 1.700 | 0.999 | 0.105 | 16.137 | 0.000 |

IV DISCUSSION

The result of the cost and return of the principal farm operator revealed that drugs and prevention costs, cost of labour, medical consultancy, cost of fertilizer, cost of planting materials, agro-chemical, transportation, feeding, wage rate, bags/sacks, processing and miscellaneous accounted for 94% of the total cost of production incurred during the operation year. The farm generated a benefit-cost ratio (BCR) of 0.82 showing that a principal farm operator losses ₦0.82 kobo for each naira invested probably due to the ill health of the principal farm operator.

The double log regression model showed that health expenditure had a significant influence on the output of farmers at a 5% level of probability. However, the coefficient had a negative sign. This implies any increase in health expenses will lead to a corresponding decrease in the output of farmers.

Transportation had a significant and negative relationship with the output of farmers. This is because the farther away a farm operator is from the treatment centre, the more cost would be incurred and this would invariably affect the output of farmers. Proximity to the nearest health centre is very crucial for effective performance. The number of times sick also had a significant influence on the output of farmers. However, the coefficient had a negative sign. This means that a unit increase in the number of times sick would most likely result in a unit decrease in the output of farmers. This is attributable to the fact that whenever a sick farmer visits any medical facilities for treatment cost is expended.

The variable farm size had a positive relationship with output. It implies that one unit increase in farm size would lead to one unit increase in output realized by the respondents. The cost of labour had an inverse relationship with output. As the cost of labour increases, the profit of farmers also reduces as a result of the fact that hiring labour for farm work becomes expensive probably owing to the non-availability of the labourer to engage in the farm to seek non-existence jobs in the urban environment.

The coefficient of cost of inputs used was negatively related to output. It means that as inputs cost decrease, the output would increase. The type of crop grown is found to have a direct relationship with output at a 5% probability. This implies a unit increase in improved varieties used will similarly lead to a proportionate increase in output. Weather condition is also found to have an inverse relationship with output. It implies that one unit increase in weather conditions would lead to one unit decrease in output. This means that a unit increase in health expenditure incurred on treatment would most likely result in a unit decrease in the output of farmers output. This is attributable to the fact that sickness is difficult to control, therefore to remain active in farming one needs to be healthy which involved cost. This means that the increase in the cost of transportation involved in treatment would most likely decrease the chances of farmers making a maximum profit in the study area. This is attributable to the fact that the presence of large farmland will enhance expansion for greater productivity. Sanni et al. (2003) found that there is a substantial association between capital, wage rate, and farm size among farmers in Kaduna state. At 5%, labour was considerable, and it had an inverse relationship with profit, suggesting that an increase in labour per unit of profit would result in a loss in profit. As production costs rise, more money is spent to cover costs rather than to enhance profit. The statement is in line with Okam, et al. (2016), who found that costs and net revenue are inversely connected. These results also support Tashikalma et al (2014) findings in Adamawa State.

The result showed that the cost of inputs had a negative relationship with output. It means that as inputs cost decrease, the output would increase as a result of the fact that the number of inputs acquired and utilized will determine

the level of profit generated by the farmer. This substantiates the findings by Mahmood, et al (2017)

The type of crop grown is found to have a direct relationship with output. The use of improved or local varieties is a strong determinant of output. The improved variety tends to generate quick turnover to activate further production. Weather condition is also found to have an inverse relationship with output. It implies that one unit increase in weather conditions would lead to one unit decrease in output. It could be that the farmers have low output because their crops were adversely affected by poor weather conditions.

The most prevalent illnesses hampering the success of the farming business of the principal farm operators were malaria, typhoid and diarrhea. The outcome of this research has shown that any occurrence of illness can affect productivity. The combined illness of malaria, diarrhea and typhoid will drastically affect labour availability for increase food production to solve the problem of food security. This finding concurred with Gbigbi (2020) that the prevalence of these illnesses can affect the productivity of the respondents.

The outcome of the study has shown that the degree of incapacitation of the principal farm operator results in a loss of days in farm business which affects output, income, and profit. They were unable expand farm land and employ more hands to assist with their farm business operations due to the illness. The reason was that farming activities required vigour due to their laborious nature. The output, farm size, and income indicated that there had been an inverse relationship with the ailment of the farmers before and during the illness. Hence, the researchers posit that ever since the farmers got ill, the expected smooth running of the farm to generate good output and income to expand farmland was hampered and the resultant effects are low profit and poor savings. Financial assistance can cushion the direct effect to a bearable minimum in the improvement of farm business activities in the study area. This result is consistent with Gbigbi (2020).

V. CONCLUSION

The findings of this study showed that arable crop farming was not profitable because the degree of incapacitation of the principal farm operator results in a loss of days in farm business which affects output, income, and profit. The contributory factors influencing the output of the farmers were health expenditure, proximity to the nearest health center, number of times sick, farm size, cost of labour, cost of inputs, types of crop grown, and weather conditions respectively. The most dominant ailment was malaria. Therefore, to ensure the reduction of the cost of illness of the principal farm operator on output, there is a need for the provision of more health centers by the government where the farmer can visit for treatment at affordable prices.

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The Effectiveness of Biosurfactants and Bioadsorbents Produced from Agricultural Waste in Treating Wastewater Polluted by Two Types of Major Pollutants: A Short-Review

KEZRANE Imane*

ABSTRACT

In the last years, water resource became endangered because of increasing pollution rate, the sources of pollution are various but mainly it is the industries which occupy the major responsibility because of their discharges which do not take into consideration neither the standards and the risk caused to the ecosystems, the industrial discharges containing toxic products as the heavy metals, the hydrocarbons, and dyes involve a dangerous impact on the environment globally and the quality of the water in particular and have a potential risk on the human health. Latest researches are based on the use of natural, biodegradable, non-toxic, readily available and non-costly bio-adsorbents.

In this context which is a bibliographic study we will show the removal efficiency by adsorption of organic pollutants (mainly dyes) and metallic pollutants present in polluted waters by using three types of bioadsorbents, the first and second types are produced from agricultural waste (potato peels and lemon peels) and the third type presents biosurfactants produced from bacterial strains.

The objective of our review is to illustrate the importance of the valorization of agricultural wastes and their use as biomass producing natural bioadsorbents and to show their elimination capacity in comparison with biosurfactants produced by bacterial strains or from a natural source in term of treatment of wastewater polluted by dyes and metals.

Keywords – Water treatment, Dyes, Metals, bioadsorbents, biosurfactants.

I. INTRODUCTION

The dyestuff industry is a major field of chemistry today. Dyes are used for printing and dyeing textile fibers, papers, leathers, furs, woods, plastics and elastomers, etc. Dyes are generally organic substances, whereas pigments are often mineral compounds (metal salts). The toxicity of dyes comes from the ignorance of the users of their chemical structures which differ from one type to another, as well as from the instructions for use. Several studies have shown the toxic effects of azo dyes, which means that effluents containing these dyes must be treated before being released into the environment.

Due to the toxicity of dyes and their dangerous impacts on the environment when discharged in an unstudied manner and the potential risk on human health, it has become very essential to research and develop methods for the removal of dye discharges from the natural environment. For this purpose, recent research has been directed towards the use of

biosurfactants which are biodegradable and non-toxic substances of microbial origin for the treatment of dye-contaminated waters.

The present work is about identification and representation of the main characteristics, properties and uses of biosurfactants, and also bioadsorbents synthesized by the potato and lemon waste as well as discussing the last researches carried out in the field of treatment of water contaminated by dyes and metals.

II. MATERIALS AND METHOD

2.1 Dyes

A dye is defined as a product capable of dyeing a substance in a durable way. It has groups that give it color: called chromophores and groups that allow its fixation: auxochromes. The synthetic dyes dominate the market today, especially since their properties can be precisely adapted to their use. Dyes are aromatic compounds whose electrons can absorb light for certain wavelengths [1]. The coloring properties of organic compounds depend on their structure and chemical composition. In general, the products used as dyes are unsaturated and aromatic organic compounds [2]. However, these dyes cause pollution once they are released into the environment. All these dyes are synthesized mainly from petroleum products, in particular benzene and its petroleum products, in particular benzene and its derivatives such as toluene, naphthalene, xylene and anthracene. They are increasingly used in the and textile industries due to their relatively easy synthesis, rapid production and variety of their colors compared to natural dyes.

The global production of dyes is estimated to be more than 800,000 t-year⁻¹ and azo dyes are the majority and account for 60-70% [3]. Synthetic organic dyes, especially azo dyes, are compounds that are highly resistant to natural biological degradation [4], Their toxicity comes from the ignorance of users of their chemical structures that differ from one type to another, as well as the instructions for use during use.

2.2 Metals

Metals are substances and materials characterized by the presence of a metallic bond between their atoms. There are several types of metals that are known to our days, namely: precious metals, ferrous and non-ferrous metals, alloys ... etc.. Their presence in the environment is either natural, which is often in the form of trace, or as a result of the activities of mining industries that are the major contributors to the pollution of ecosystems by metals due to their untreated discharges.

2.3 Biosurfactants

Of all the surfactants we know today, the oldest is soap. The first users of soap were the Sumerians in 2500 B.C. They made soap bars from vegetable or animal oils. Since the 1950s, soap has been replaced by synthetic surfactants in detergent formulations [5].

These tensioactives, also called surfactants or surface agents, are natural or synthetic molecules, consisting of two parts of opposite affinity (Figure 1): a hydrophobic, lipophilic part or apolar tail and a hydrophilic part or polar head. Today, these detergents of natural source or more precisely these Biotensioactives are known as "Biosurfactants".



Figure 1. Schematic representation of a surfactant.

They are surfactants present a group of amphiphilic chemicals that contain both hydrophilic and hydrophobic parts in the molecular structure. The choice of the biosurfactant used in the removal of pollutants from contaminated water is related to the nature of the water to be treated and the type of pollutant and its composition, these factors play a very essential role in the process of removing such a pollutant.

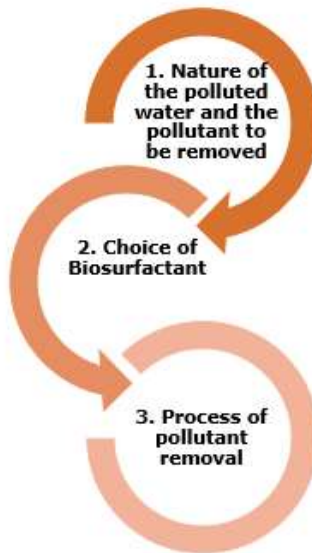


Figure 2. The relation between the type of polluted water, choice of biosurfactant and the process of pollutant elimination.

The production of biosurfactants can be achieved by using different microorganisms, the composition of the culture medium and its conditions (temperature, pH, Aeration and Agitation, Salt concentration.) as well as the nature of the carbonaceous substrate used and Nitrogen Source have a direct influence on the production of biosurfactants [20,25]. Biosurfactants can be classified into two classes:

a. low molecular weight biosurfactants that are effective in lowering surface and interfacial tension. The main classes of this type of biosurfactants are: glycolipids, lipopeptides and phospholipids.

b. high molecular weight biosurfactants that are very effective as emulsifiers and stabilizers. emulsifiers and stabilizers. This class of biosurfactants also includes polymers.

Most biosurfactants from various microbial strains are either anionic, cationic or neutral and the hydrophobic moiety is based on a long chain of fatty acids or fatty acid derivatives, while the hydrophilic portion can be a carbohydrate, a phosphated amino acid or cyclic peptide [21,22].

The figure below shows the different types of biosurfactants:

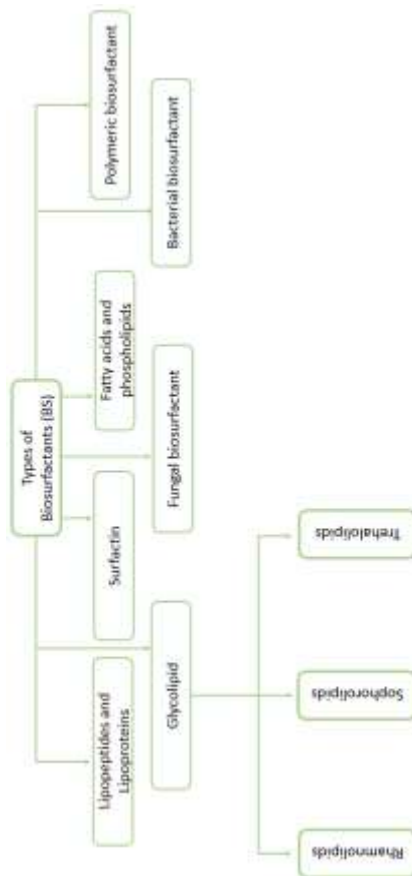


Figure 3. Types of Biosurfactants [23].

Biosurfactants are primarily produced by microorganisms growing aerobically in an aqueous medium containing one or more carbon sources, such as carbohydrates, oils or hydrocarbons, [24]. The microorganisms producing biosurfactants are:

a. Bacterial genera: Rhodococcus, Arthrobacter, Brevibacterium, Mycobacterium, Corynebacterium, Acinetobacter, Pseudomonas, Bacillus. Mycobacterium, Corynebacterium, Acinetobacter, Pseudomonas, Bacillus.

b. Fungal genera: Torulopsis, Candida, Pseudozyma, Yarrowia, Kluyveromyces and Saccharomyces Kluyveromyces and Saccharomyces.

2.2 Bioadsorbents

Bioadsorbents (BA) are biodegradable and non-toxic compounds. They are of natural origin (Zeolite and silicates), or biologically synthesized using different microorganisms or bacterial strains, their production is influenced by the composition of the medium and by the conditions of culture (Fungi, Bacteria,), or produced from agricultural waste, industrial waste and certain by-products (e.g. orange peel, banana peel, potatoes, animal fat, olive waste and coconut oil..). Within all the raw materials for the production of bioadsorbents, we are interested in bioadsorbents synthesized from agricultural by-products and wastes as it makes possible the production of cheap bioadsorbents and allows the use of waste substrates while reducing their polluting effect.

Recent research has been directed towards the use of natural biodegradable and non-toxic adsorbents that are readily available, in our review we have chosen the studies examined on the potato residue and lemon peels as a bioadsorbents because of the availability of this vegetable species all around the world and that is widely consumable and by the following we guarantee a large amount of waste (peels) that can be valorized as a bioadsorbent. The potato peels and Lemon peels can be used for the treatment of water polluted by various contaminants. They meet the critical requirements for the bioremediation of contaminated waters.

2.3.1 Synthesis protocol of bio-adsorbent based on Potato Peels (PP)

The peels are used as raw material for the production of bioadsorbent. The peels should be washed several times with distilled water and then dried in an oven (Binder) at 393 K for 24 hours to remove moisture, The dry material was crushed and then sieved to a uniform particle size of 0.45-0.15 mm as a raw powder [6]. In order to have a better pollutant removal result using a bioadsorbent synthesized from agricultural waste, it is necessary to go through a chemical activation step (use of phosphoric acid H₃PO₄, sodium hydroxide NaOH, sulfuric acid H₂SO₄, zinc chloride ZnCl₂, potassium hydroxide KOH...) or thermal (use of high temperature up to 600K) or both at the same time.

2.3.2 Synthesis protocol of bio-adsorbent based on lemon peels

The peels are used as raw material for the production of bioadsorbent. The peels must be washed several times with distilled water and then dried in an oven (Binder) at 110 ° C for 24 hours to remove moisture, then we pass to the thermal activation at a temperature between 400 K and 450 K for 90 minutes, after the activation we must remove the ash by washing the activated carbon with double distilled water, Then it is dried in an oven at a temperature of 110 °c for 19 hours and finally our material will go through the sieving on a mechanical agitator (Fritsch) to obtain at the end an activated carbon (bioadsorbent) of a size ranging between 20-90nm in a powder form [26]. At the end of the bioadsorbent synthesis we can add a last treatment step to improve the quality of the bioadsorbent and to have a good adsorption capacity by a physical regeneration (heating, microwaving, sonication, pyrolysis) or chemical (use of acids, alkyl, organic solvents) [27].

III. RESULTS

Tables 1, 2 and 3 below show the results of some studies that prove the efficiency of adsorbents produced from potato waste, lemon waste and biosurfactants respectively.

Table 1. Results obtained by the use of PP in the treatment of waters polluted by different pollutants.

| Eliminated dye | Technique used | Results | References |
|-----------------|---|--|------------|
| Methylene blue | Exploration of the adsorption mechanisms of cationic and anionic dyes on agricultural waste peels | The maximum adsorption capacities for BM and OG on potato peels were found to be equal to 107.2 mg/g and 23.6 mg/g respectively. | [6] |
| Orange G | | | |
| Malachite green | Use of PP chemically modified with H ₂ SO ₄ and HCHO for dye adsorption from polluted water | Potato Peels activated with H ₂ SO ₄ allowed the removal of 86% of the initial load and PP activated with HCHO allowed the removal of 93.3% of the initial pollutant load. | [13] |

| | | | |
|---------------------------|---|---|------|
| Crystal violet | Use of natural protein derived from sweet potato. | Pollutant removal rate reached 95.8%. | [14] |
| Methylene blue | Use of stem potato and leaves without any modification. | Removal of 82% of blue methylene and 67% of malachite green for an initial concentration of 10g/L of pollutant. | [15] |
| Malachite green | | Removal of 87% methylene blue and 75% malachite green by using Potato Leaves for an initial concentration of 10g/L of pollutant. | |
| Copper II | Thermal modification at a temperature of 973 K | Elimination of copper II from aqueous solutions with a removal rate of 99.8% at a pH equal to 6 and a stirring time of 20 minutes | [33] |
| | chemical modification using ZnCl ₂ added to a thermal activation. | The study showed that pyrolysis of potato peels impregnated with chloride-zinc produces materials with a well-developed pore structure and high adsorption capacities, allowing contact areas as high as 1078m ² /g and pore volumes as large as 0.97cm ³ /g. | [35] |
| Cd, Cu, Ni, Zn, Mn and Fe | Use in its raw state | A higher sorption rate compared to canola and walnut shell was indicated which equal to 50.2% with an equilibrium time for metal sorption by potato peel in the order of : 200, 80, 120, 200, and 120mn for Cd, Cu, Ni, Zn, Fe, and Mn respectively | [34] |
| Cobalt(II) cation | the use of H ₃ PO ₄ for chemical modification and thermally activated | The maximum theoretical adsorption capacity (Q _m) for Potato peels bioadsorbent activated at 400 °C was 373 mg/g, while Potato peels produced bioadsorbent at | [36] |

| | | | |
|--|--|------------------------------------|--|
| | | 600 °C was even higher (405 mg/g). | |
|--|--|------------------------------------|--|

Table 2. Results obtained by the use of LP in the treatment of waters polluted by different pollutants.

| Pollutant | Type of modification or activation | Results | Reference |
|---------------------|--|--|-----------|
| Methylene blue (MB) | -Addition of orange peels. -Chemical activation by phosphoric acid. -Thermal activation at T= 600°C. | Maximum adsorption capacity equal to 33 and 38 mg/g for methylene blue and orange methyl respectively, at pH(MB)=6; pH(MO)=2 and Equilibrium contact time=30min Elimination rate: R (MB)= 98% R (MO)= 96% | [28] |
| Methyl orange (MO) | | | |
| Eosin dye | -Thermal activation at T= 425 K. | Maximum adsorption capacity equal to 8.24 mg/g, at pH=2 and equilibrium contact time equal to 60 min. | [26] |
| Nickel (II) ions | -Chemical activation by NaOH. | At pH=5 and 3 hours of contact time, a 100% elimination rate was achieved. | [29] |
| | -Chemical activation by TiO ₂ | A removal rate of 90% was obtained when using chemically modified bioadsorbent | [30] |
| | -Raw form | A removal rate of 78% was obtained when using bioadsorbent at the raw form. | |
| | -Thermal activation at | | |

| | | | |
|-------------|------------------------------|---|------|
| Colbat ions | T=500 °c | At pH=6, equilibrium contact time equal to 10 hours, maximum adsorption capacity of 55 mg/g was achieved. | [31] |
| Lead | -Chemical activation by NaOH | After 6 hours of contact time, at pH=1, a removal rate of 100% was achieved. | [32] |

Table 3. Results obtained by the use of some biosurfactants in the treatment of water polluted by different pollutants

| Used Biosurfactant/Produced strain | Pollutant | Technique used | Results | References |
|------------------------------------|----------------|---|--|------------|
| Rhamnolipid BS | Congo red | Adsorption by using a <i>Pseudomonas taiwanensis</i> L1011 produced BS | Surface tension retention up to 25.8mN/m | [7] |
| | Methylene blue | Elimination of dye pollutant by flotation | Removal of 97 ± 0.13% of initial dye concentration | [8] |
| Lipopeptide BS | Textile dyes | Combination of <i>Kurthia gibsonii</i> KH2 bacterial strain to produce the BS and using it in degrading dye process | 85% discolouration percentage | [9] |
| Saponin | Methyl violet | MEUF processes | Removal of 99% of the load | [10] |
| | | Chemical treatment of BS by H ₂ SO ₄ and physical modification | Removal of 95% of the load | [11] |

| | | | | |
|-----------------|--------------------|---|---|------|
| | Reactive red 241 | Adsorption of dye using of the dead leaves of saponin | Removal or 95% of initial dye concentration | [12] |
| Rhamnoli pid BS | Manganese (II) ion | the use of locally produced biosurfactant membrane by <i>Pseudomonas aeruginosa</i> ATCC 10145 strain. | In a contact time equal to 2 minutes an elimination rate of 77% was achieved | [38] |
| | Chromium (III) | FeSO ₄ was used for precipitating Cr(VI) to Cr(III) which was then eliminated by flotation. | The removal of 40 ppm of the initial Cr(III) concentration within the first 5 minutes equals a removal efficiency of 95%. | [39] |
| | Cadmium (Cd) | addition of a biosurfactant produced by <i>Pseudomonas aeruginosa</i> strain MA01 to the coal waste and production of an new adsorbent. | after 10 hours of reaction between the produced biosurfactant and the adsorbate to be removed (Cd) and at a pH of 9, a removal rate of 99% is reached | [40] |

IV. DISCUSSION

1 Using of bioadsorbents produced from potato peels (PP) waste

When we talk about the potato field, it is necessary to specify the point that the breed of PP studied is an important information concerning the composition of the peels, for this reason several techniques can be used to characterize the bio-adsorbent produced in order to have a more detailed idea on the fundamental characteristics of the microstructure of the biomass produced, in particular: SEM (Scanning Electron Microscopy), FTIR (Fourier Transform Infrared Spectroscopy), XRD (X-Ray Diffraction). Based on observations and characterization made by many researchers,

they have affirmed the adsorbing nature of the surface of potato peels (PP) in their raw state before any chemical or thermal modification or activation. The peels contain starch aggregates which present on their surfaces pores of variable diameter, for the functional groups the hydroxyl group is the most predominant, as well as the carboxyl group and of a certain proportion the oxygen-containing functional groups (OH, C=O and C-O), these three groups are responsible for the electrostatic interaction between the adsorbate and the adsorbent as in the case of methylene blue dye, which subsequently ensures the type of chemical adsorption [6,18]. Table 1 below shows the efficiency of bioadsorbents synthesized with potato peels used in the treatment of water polluted by dyes.

Tahseen. A et al (2008) studied the removal of one of the heavy metals (Copper II) from wastewater and industrial effluents using potato peels as solid waste with the aim of estimating the optimal adsorption conditions as well as studying the kinetics and isotherms of adsorption and also the effect of different parameters. According to the results obtained, potato peels have demonstrated their efficiency and potential of use as an excellent adsorbent for the removal of copper II from aqueous solutions with a removal rate of 99.8% at a pH equal to 6 and a stirring time of 20 minutes [33]. In another study J.C Moreno and L.Giraldo (2011) used an activated carbon obtained by pyrolysis of potato peel for the removal of copper (II) from aqueous solutions with the objective of proving the possibility of obtaining from potato peels carbon adsorbents with high surface areas and pore volumes and that the development of the pore structure can be modulated by changing the relative proportions of the raw material and ZnCl₂. In summary the study showed that pyrolysis of potato peels impregnated with chloride-zinc produces materials with a well-developed pore structure and high adsorption capacities, achieving contact areas as high as 1078m²/g and pore volumes as large as 0.97cm³/g [35].

Also Morteza.F and Mohsen. J (2015) carried out research on heavy metal removal from aqueous solutions using sunflower hull, potato, canola and walnut shell residues, the objective of their work was to estimate the sorption of heavy metals (Cd, Cu, Ni, Zn, Mn and Fe) as a simple and competitive sorption phenomenon from aqueous solutions, as well as to study the sorption kinetics of these metals, and to evaluate the effect of chemical activation of the sorbents on the sorption performance. SEM images of the activated sorbents showed a porous and fibrous structure, chemical activation of the biosorbents by NaOH resulted in an increase in their sorption capacity for Ni. Regarding the results obtained by using potato residues: a higher sorption rate was indicated which equal to 50.2% with an equilibrium time for metal sorption by potato peel in the order of: 200, 80, 120, 200, and 120mn for Cd, Cu, Ni, Zn, Fe, and Mn respectively [34]. And according to a study conducted by Edidiong D.A and Alastair D.M (2016) with the purpose of examining the potential of using an agricultural residue

(sweet potato peels) as an adsorbent for the removal of Cd (II) ions from an aqueous solution, Examination of the influence of some parameters such as pH, contact time, and initial concentration of the Cd (II) ion on the sorption process was also considered. Physical and chemical characterization of the agricultural residue of sweet potato peel was also performed to determine its intrinsic characteristics and their effect on sorption. The results showed that the optimum pH range for adsorption was between 6.5 and 7. The kinetics of Cd(II) ion removal indicated an optimal contact time of 180 min via a two-step kinetic adsorption profile (fast initial equilibrium and then slow), as well as the monolayer adsorption capacity of the sweet potato peel adsorbent was estimated to be 18.9 mg/g [37].

S.Boumchita et al (2016) conducted a study on the removal of Methylene Blue (cationic dye) from aqueous solution by a food waste which potato peel as a natural adsorbent, the objective is to study the adsorption process as a practical and economical method for dye removal , the results showed that the mass of adsorbent plays a vital role as the removal percentage increases from 61. 4% to 87.6% when the concentration of adsorbent is 0.5 to 1.5 g.L-1 respectively, the contact time also affects the rate of adsorption with an adsorbed amount equal to 92% during the first five minutes, on the other hand, the temperature has an adverse effect on the percentage of dye removal [18]. A.Stayrinou et al (2018) explored the adsorption mechanisms of cationic and anionic dyes on agricultural waste peels, especially potato peels for the treatment of wastewater polluted with the dyes (Methylene Blue-BM, Orange G- OG) by the different agricultural waste and the influence of the structure of each of them on the adsorption phenomenon. The results showed that the maximum removal efficiency of BM was observed at $\text{pH} \geq 6$ while the removal of OG was maximized at $\text{pH} = 2$. The maximum adsorption capacities of BM and OG on PP were in the range of 107.2 mg/g and 23.6 mg/g respectively. Based on the results of this work, potato peels, which are all found in abundance in nature, can be used without any modification and could be considered as very low-cost biosorbents for the effective removal of anionic and cationic dyes from wastewater [6].

The potato residue is a easily available product, which does not require a large experimental protocol in the production of the derived biomass and which gives very good results in the field of water treatment, the studied works show many prospects for future research related to the development of water treatment processes by means of potato peels. Table 01 shows such high adsorption capacities in the case of treatment of organic pollutants, which proves the effectiveness of potato peels in the treatment of different types of contaminants. The temperature, the contact time, as well as the initial concentration of pollutant play a very important role in the adsorption process carried out. The activation temperature and the use of acids in the chemical activation have shown a positive influence on the obtaining of high carbon products and the removal rate of the pollutants.

2 Using of bioadsorbents produced from Lemon Peels (LM) waste

According to the table 2, it can be seen that the use of bioadsorbents in their raw state or after chemical or thermal activation influences the maximum adsorption capacity as well as the rate of pollutant removal. This is related to the condition of the bioadsorbent surface, the morphology before and after modification, the diameter of the available adsorption sites. Also the pH of solution plays a role on the adsorption phenomenon and it is noticed that the optimal pH value for the case of using lemon peels as bioadsorbent varies between 1 and 6. The initial concentration of bioadsorbent and pollutant influence on the equilibrium time and when increasing the dose of bioadsorbent an increase in removal rate is noticed.

3 Using of Biosurfactants

It should be noted that microorganisms are capable of synthesizing surfactants called biosurfactants. Thus, research is focused on the production of these surfactants of microbial origin. These biosurfactants have several advantages: They can be produced from inexpensive and easy to obtain substrates (such as waste from the food industry), and they can be used in the production of substrates (such as waste from the food industry or manufacturing by-products). Biosurfactants have attracted interest from different industries due to advantages such as structural diversity, low toxicity, increased biodegradability, ability to operate in wide pH, temperature and salinity ranges as well as higher selectivity, lower CMC and production involving renewable sources/industrial waste and industrial by-products [16].

Almost all studies carried out on surfactants prove their effectiveness and their important role in the remediation of contaminated waters and in particular the dyes. The table 2 below shows the efficiency of some biosurfactants used in the treatment of water polluted by dyes.

Most biosurfactants derived from various microbial strains are either anionic, cationic or neutral [18] and the hydrophobic moiety is based on a long fatty acids or fatty acid derivatives, while the hydrophilic portion can be a carbohydrate a carbohydrate, a phosphated amino acid or a cyclic peptide. K.samal and K.mohanty (2017) studied the application of saponin biosurfactant and its recovery in MEUF process for the removal of methyl violet from wastewater, the study of pH effect shows a slight increase in the solubilization of methyl violet on increasing the pH up to 7 and beyond pH 7, the solubilization started to decrease, The percentage of removal of methyl violet was more than 99% in the different conditions studied [10], and in order to study the solubilization characteristics, Samal. K et al (2018) performed another study on the solubilization of two different dyes, methylene blue and eosin yellow, by a biosurfactant, saponin, their test of the effect of pH in the range between 3 and 12, 5 and observed that the pH does not have much effect on the solubilization of the eosin yellow dye but

affects the solubilization of the methylene blue dye in the saponin micelle, also, the introduction of salts (NaCl) in the surfactant solution allows to observe that its increase introduces an increase of solubilization [11]. In another study of M. Bielska, and J. Szymanowski (2006) they studied the removal of methylene blue from wastewater by micellar ultrafiltration, The objective of their work was to study the removal of methylene blue by MEUF (micellar-enhanced ultrafiltration) of micellar solutions containing anionic (SDS) and non-ionic (OMC-10) surfactants, The introduction of a non-ionic surfactant in SDS decreased the CMC of the mixed micelles from 8.3×10^{-3} to 2×10^{-3} M which proves that a tailor-made surfactant mixture achieved 93-94% retention of methylene blue [19]. Based on the results of these two previous studies on the treatment of methylene blue polluted waters, it is noted that both surfactants have given good results underlining the fact that saponin is a biosurfactant and SDS and OMC are synthetic surfactants, therefore it is concluded that the use of a biosurfactant that does not present any risk on the nature remains useful and is competitive with chemically synthesized surfactants. As shown in Table 02, whatever the nature of the biosurfactant, whether it is a product of a bacterial strain or a natural source, it gives good results in terms of dye removal.

V. CONCLUSION

Several studies carried out on bioadsorbents prove their effectiveness and their important role in the remediation of contaminated waters. The adsorption process is the most studied and used phenomenon to know and predict the distribution of bioadsorbents in the solution containing the pollutants because of the variety of isotherms that it distributes. Despite all the advantages of biosurfactants in comparison with chemically produced surfactants and despite their use in the field of water treatment on several pollutants, such as dyes, heavy metals, oil wastes ..ect, and the high removal rates found but their synthesis and applications remains limited to the laboratory scale in the majority of cases.

In order to compare the three types of adsorbents presented above (PP bioadsorbent, LP bioadsorbent and biosurfactants), all of them are effective and give mixed and respectable results, this is the advantage of using each of the three adsorbents, but if we have to choose the best among them, as an author I find that the use of bioadsorbents produced on the basis of agricultural waste has more advantages, First of all, it allows the valorization of a biomass that was a waste, it is a material that is 100% natural in the case of use in its raw state, their modification and treatment is easier and not expensive compared to biosurfactants that require in most cases to prepare an optimal culture medium and / or add other additives to improve their adsorbent power.

In conclusion, biosurfactants and also bioadsorbents produced on the basis of potato peels and lemon peels have a great solubilizing and eliminating

power (with an elimination rate that varies from one to another) of dyes and metals, both have an adsorbent character and can be used as eco-friendly substance to treat polluted water and prevent the environment from pollution due to chemically synthesized adsorbents.

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