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" Physical Drivers and Stranded Assets in Agriculture: The Case of Honduras"

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Abstract

Stranded assets are those that do not generate expected returns and have become a growing concern in agriculture due to environmental related risks. Honduras is a developing country extremely vulnerable to climatic phenomena which makes agriculture face challenges that threaten its profitability. This study aims to gather information on the physical factors associated with climate change and its economic impact on Honduran agriculture. Some of the physical factors mentioned in this study are climate variability and water scarcity, soil degradation, loss of biodiversity and ecosystem services, and phosphate availability in the middle and long term. To address these challenges, it is crucial to take urgent measures to promote sustainable agricultural practices. Collaboration between universities, businesses and governments plays a key role in mitigating the effects of climate change and achieving a successful transition to a more resilient and sustainable agriculture. Through the implementation of adaptive strategies, research, and innovation, it is possible to overcome the current and future challenges of Honduran agriculture, ensuring the sustainable development of the country.

Keywords: stranded assets, drivers, climate, scarcity, sustainable.

Resumen

Los activos varados son aquellos que no generan la rentabilidad esperada y se han convertido en una preocupación creciente en la agricultura debido a los riesgos relacionados con el cambio climático. Honduras es un país en desarrollo extremadamente vulnerable a los fenómenos climáticos, la agricultura se enfrenta a retos que amenazan su rentabilidad. Este estudio pretende recopilar información sobre los factores físicos asociados a riesgos medioambientales y su impacto económico en la agricultura hondureña, incluyendo la variabilidad climática y la escasez de agua, la degradación del suelo, la pérdida de biodiversidad y de servicios ecosistémicos, y la disponibilidad de fosfatos a mediano y largo plazo. Para hacer frente a estos retos, es crucial tomar medidas urgentes para promover prácticas agrícolas sostenibles. La colaboración entre universidades, empresas y gobiernos desempeña un papel clave para mitigar los efectos del cambio climático y lograr una transición exitosa hacia una agricultura más resistente y sostenible. A través de la implementación de estrategias adaptativas, investigación e innovación, es posible superar los retos actuales y futuros de la agricultura hondureña, asegurando el desarrollo sostenible del país.

Palabras clave: activos varados, factores impulsores, clima, escasez, sostenible.

Introduction

Stranded assets are investments that lose value or fail to generate expected profitability. These assets can become liabilities due to various factors, such as: changes in the regulatory environment, market conditions, societal norms, technology, financial contexts, and environmental risks. Unexpected shifts in these factors can lead to premature retirement, costly retrofitting, or diminished profitability of investments (Bos & Gupta, 2019, p. 4). However, these risks are not well understood, leading to a significant over-reliance on unsustainable assets in our financial and economic systems (Caldecott et al., 2013).

In other words, “stranded assets” are investments that have become worthless (Kraemer, 2017). To date, research on stranded assets has primarily focused on the fossil fuel sector, notwithstanding, with increasing recognition of climate change's potential to create stranded assets, it is evident that the risk extends beyond energy. Agricultural assets are also vulnerable to stranding due to physical impacts like drought and desertification, as well as regulatory and technological changes (Rautner et al., 2016).

While stranded assets can be caused by a number of risks, environmental considerations are now a more common cause. This tendency is picking up speed and has an impact on asset values across several industries. When environmental concerns are underappreciated and improperly considered when determining an asset's worth, the asset may first appear to be valuable in a company's financial statement. The asset, however, loses profitability as dangers become increasingly apparent, often quickly, to the point where it may be abandoned before the end of its estimated useful life (Caldecott, 2015).

Agriculture is the basis of human subsistence, as it provides the necessary food for people's survival and is also a significant sector of the global economy. The consecution of global development objectives relies heavily on the presence of robust, environmentally friendly, and equitable food systems. The advancement of agriculture stands as a potent instrument in eradicating severe poverty,

fostering collective well-being, and providing sustenance for an estimated 9.7 billion individuals by the year 2050 (The World Bank, 2023a).

Nevertheless, agricultural assets face a loss of value due to various risk factors. Currently and in the future, there are various risks that could lead to "stranded assets" due to physical factors such as physical water scarcity and climate change, land degradation, diseases, viruses and pests, loss of biodiversity, and collapse of ecosystem services. The implications of these changes can render certain crops unviable or unprofitable in specific regions, ultimately resulting in these crops becoming stranded assets.

The loss of value of agricultural assets poses a direct threat to the economies of countries, particularly those where agriculture is a significant contributor to their GDP (Gross Domestic Product), such as Honduras. In addition, stranding risks can affect multiple stakeholders in the agricultural supply chain. This includes landowners or rights holders, infrastructure owners involved in transportation and processing products, companies, and investors (Rautner et al., 2016).

Therefore, to effectively address the issue of stranded assets in agriculture, it is important to identify the drivers that are generating losses in the agricultural sector in order to take mitigating and preventive actions. According to Caldecott et al. (2013), the climate risks that agriculture may face are divided into economic and physical risks according to their impact on agricultural crops.

In the context of Honduras, this analysis will examine the effects of multiple physical drivers on agriculture. These drivers include heightened weather variability, physical water scarcity, climate change, land degradation, biodiversity loss, the decline of ecosystem services, the amplified risk of agricultural diseases, viruses, and pests, and the long-term availability of phosphate.

Considering the mentioned factors, this literature review has two main objectives. Firstly, it seeks to explore the connection between physical drivers and the emergence of stranded assets in the agricultural sector. Lastly, it aims to identify potential solutions or approaches to mitigate the risks associated with stranded assets in Honduras' agricultural sector.

Methods

For this literature review, data was collected from secondary sources found on the Internet. Mainly information was obtained from reports of international organizations, scientific journals, books, and Internet documents. Some of the consulted sources belong to organizations such as the Food and Agriculture Organization (FAO), The World Bank, Interactive Country Fiches, which works with the European Commission, and the United Nations Environmental Programme (UNEP). Additionally, the United States Agency for International Development and the Global Environmental Facility were also consulted, among others. Similarly, books such as the Stranded Assets Programme of The Smith School of Enterprise and the Environment at the University of Oxford were an important source to determine the physical factors to investigate in the country.

The acquired facts and information were carefully arranged into several sections within the review. Through division, the entire information was intended to be made clearer and easier to comprehend.

Results and Discussion

Stranded Assets in the Agriculture Context

Agriculture is a very dangerous sector because it depends on many external factors beyond the farmers' control. One of the biggest problems currently facing this sector is climate change. Farm and household incomes and stability may be adversely affected by this phenomenon. Changes in productivity, production costs and prices are indicators of these impacts. As a result, farmers may be forced to sell profitable assets such as livestock, reducing their ability to generate cash over a long period of time. Hazards related to the effects of climate change may also deter investment in industrial systems, resulting in reduced productivity, profitability and sustainability over time (Food and Agricultural Organization [FAO], 2015).

The main problem of agriculture is its excessive dependence on natural capital. An example of this is that the natural capital cost of livestock and agricultural activities is more than 7 times greater than the profits derived from these activities (Caldecott, 2015). Economic activities depend mainly on natural capital, the world's reserves of natural assets that are being depleted mostly by unsustainable agriculture (McKinsey & Company, 2022). Another problem in agriculture is rising prices for agricultural commodities, as this can be counterproductive in the long run. This increase is due to increased demand from a growing world population, technological advances, favorable policies, or market speculation. In addition, other economic sectors are receiving less investment due to lower economic returns compared to agriculture and unfavorable investment climates. However, concern arises when considering the potential for blocked assets. If the agricultural boom failed or if commodity prices fell significantly, inflated farmland values could become unsustainable. This could result in landowners and investors being left with assets worth less than what was initially paid for, creating financial challenges and stranded assets (Caldecott et al., 2013).

As mentioned above, environmental risks in the agricultural supply chain can lead to stranded assets, affecting various sectors, assets and even commodities or entire regions. This connection

highlights the implications and challenges associated with climate change and its effects on agriculture. The effects of climate change are considered a direct cause of asset and resource stranding, such as the effects of increased weather variability, floods or droughts on agricultural assets and resources (Bos & Gupta, 2019).

Agriculture in Honduras

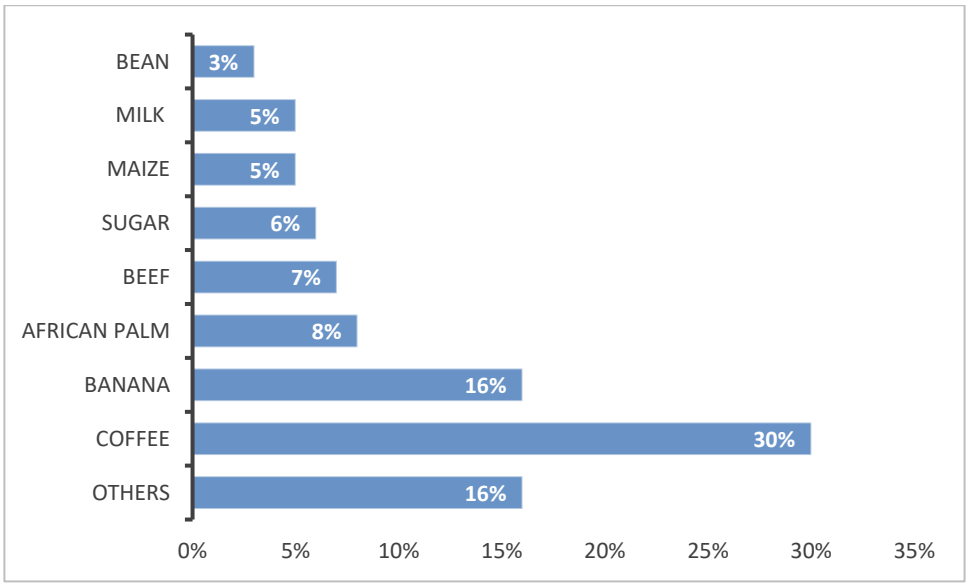
Agriculture is the main income generator for Hondurans living below the poverty line. In addition to creating employment, it contributes to 12.6% of the nation's Gross Domestic Product. Nearly 30% of the Honduran population works in the agricultural sector (The World Bank, 2023b). Furthermore, the majority, around 70%, are smallholders who are mainly engaged in less profitable crops such as bananas, rice, corn, and beans (Berg et al., 2022).

Honduras has two distinct agricultural systems, with a modern large-scale production system coexisting alongside smaller, resource-limited subsistence and semi-subsistence systems. In Honduras, large-scale farming is generally located on the most fertile land and is responsible for the country's primary agricultural exports, such as coffee, bananas, African palm oil, sugarcane, melons, and pineapples. In contrast, small-scale farmers typically cultivate poorer quality soils, with the exception of coffee, which accounts for more than 90% of the country's total coffee production (Jacinto, 2019).

In the following figure we can observe the share of the value of each agricultural product within the sector for 2017.

Figure 1

Main Agricultural Products in Honduras, as a Percentage of Total Production Value in 2017



Note. Taken from Derlagen et al. (2019)

It can be observed that coffee is the product with the highest total monetary value of all agricultural products produced in that year in the country. It is followed by bananas, African palm, beef and sugarcane, corn, milk, and beans, in that order.

However, the problem is that agriculture in Honduras has faced significant challenges in recent years, such as climate change, lack of access to financing and technology, low productivity, and lack of competitiveness in international markets. Honduras faces multiple challenges, including climate change, violence, and external shocks, resulting in increased vulnerability to natural disasters and a high homicide rate. In addition, the agricultural sector has suffered a decline in income of almost one-third over the past 20 years due to the fall in prices of export crops, especially bananas and coffee (International Fund for Agricultural Development [IFAD].

In the Honduran context, the lack of understanding of stranded assets poses significant challenges for stakeholders in the agriculture sector. These stakeholders face the daunting task of managing a complex network of interconnected environmental and economic risks when determining how to allocate resources and make investments in the food value chain.

Agriculture in Honduras, especially at the small scale, grapples with vulnerability to significant shocks that can disrupt harvests, earnings, and entire livelihoods over short time horizons. The agricultural sector in Honduras faces the risk of losing entire harvests due to various large-scale and challenging-to-prevent events such as climate-related disasters and diseases. An example of this was seen in the aftermath of Hurricanes Eta and Iota, where the Honduran government estimated significant crop losses. Approximately 8,200 hectares of maize and 12,850 hectares of beans were lost to extreme weather conditions (Berg et al., 2022).

Physical Water Scarcity and Climate Change

Honduras is highly susceptible to climate change due to its geographic location, its agriculture-dependent economy, and the vulnerability of its population to natural disasters. Honduras, situated in the Americas, stands as one of the most impoverished nations and faces significant susceptibility to climate change-induced occurces like hurricanes, tropical storms, droughts, and landslides. These events have detrimental effects on agriculture and infrastructure within the country (The World Bank, 2021). The Global Climate Risk Index ranked Honduras as the second most affected country globally by extreme weather events between 1998–2017 (Eckstein et al.).

Furthermore, in the coming years, the climate is expected to undergo significant changes, including a rise in the average temperature of 1 to 2.5 degrees Celsius by 2050 and 3 to 4.3 degrees Celsius by 2100. Additionally, there may be a decrease in annual rainfall by 9 to 14 percent by 2050 and 20 to 31 percent by 2100 (United States Agency for International Development [USAID], 2017). The fluctuations in temperature and rainfall have a significant impact on agriculture in Honduras and worsen the already severe socioeconomic conditions, resulting in elevated poverty rates, food insecurity, and the displacement of entire communities. Regarding the economic sphere, a 1°C increase in average temperature would translate into a decrease of approximately US$2.14 per month in agricultural earnings. Therefore, if the temperature rises by 2°C, average monthly agricultural

earnings would decrease by 9%, which represents about 3% of the total monthly income of rural Honduran households (Ordaz et al., 2010, p. 1). Moreover, the population is mainly affected by a sharp rise in the price of basic food basket products and fuels; a decrease in the production of basic grains such as corn (65%) and beans (75%) due to climatic reasons, limited access to inputs or fear of crop losses, resulting in an increase in the prices of these basic foods in the Honduran diet (Gobierno de la República de Honduras & The Central American Integration System [SICA], 2022).

Given that Honduran agriculture is heavily reliant on climatic conditions, the impact of climate change on the country's agricultural production would be substantial. This could alter the areas suitable for growing agricultural products for export and food security for farmers. As a result, some geographical areas may gain productive capacity for certain crops, while others may lose it in the future (Bouroncle et al., 2014).

Honduras's production of corn, coffee, and beans has suffered the effects of climate change the most, causing stress, low crop yields, decreased quality of crops, and crop losses ranging from partial to total (Berg et al., 2022). According to key information on different crops provided by CIAT in 2019, Honduras is expected to face significant challenges related to climate change impacts on its agriculture. Maize, which is rainfed by 93% and has an overall poor productivity of below 2 MT, is estimated to experience an average productivity decrease of 14% by 2050 due to climate change, double the global average. Sugarcane, which is rainfed by 76%, is expected to face an average loss of 37% until 2050. Coffee revenues are predicted to decrease by 26% overall by 2050 due to various factors, and while beans are expected to experience losses due to climate change, these losses are anticipated to be moderate by 2050 (Jacinto, 2019).

Regarding African Palm, climate change does not significantly affect this crop. During the period between 2010 and 2050, in the absence of climate change, there is an expected 19 percent increase in palm oil yield, which is nearly equivalent to the projected increase under the median climate change scenario (Sanders et al., 2019). In addition, banana cultivation have been affected by

extreme weather events, in 2020, approximately 27% of Honduras' banana production, was negatively affected by hurricanes Eta and Iota, which caused losses of US$17 million (Lievens, 2021).

On the other hand, livestock activities are considered less sensitive to climate change, but there are still potential impacts. These include heat stress, reduced milk production in cattle during the dry season, and limited grazing forage due to longer and more severe droughts. Climate change may also increase the prevalence of livestock diseases and parasites. While livestock activities may not be highly vulnerable, it is crucial to acknowledge and address these potential effects (Sanders et al., 2015).

Additionally, Honduras faces another significant challenge, which is the issue of water scarcity. Despite having abundant water in some regions, Honduras faces significant challenges in accessing clean water. Surface water quality is compromised by deforestation, agricultural runoff, and mining, while groundwater is vital for certain communities. However, limited storage facilities worsen water scarcity, which will be intensified by climate change impacts. Rapid urbanization and insufficient investments have led to declining water services. Addressing these challenges requires sustainable water management and increased investment in water infrastructure. Honduras has few storage facilities, so water shortages will become worse as higher temperatures and lower rainfall intensify the drought cycle, reduce surface flows, and lower groundwater levels, mainly in the Dry Corridor (USAID, 2017)

According to a study conducted by IHCIT - UNAH in 2011, it was found that 19% of the country experiences water scarcity, 5% has an abundance of water resources, and 76% has an average level of water availability. In particular, water scarcity was observed in ten departments. These departments include Valle (64.18%), El Paraíso (43.84%), Cortés (39.07%), Francisco Morazán (30.18%), Olancho (29.39%), Yoro (27.41%), Comayagua (23.49%), Santa Bárbara (19.04%), Copán (18.83%), and Choluteca (17.36%) (Interactive Country Fiches, 2023b).

Water scarcity can have significant effects on different crops. An example of this is Arabica coffee, which grows optimally in temperatures ranging between 18 and 22 degrees Celsius. Similarly, the bean crop also shows better performance under optimal temperature conditions. However, maize production is negatively affected when the temperature exceeds 30 degrees Celsius. In Honduras, for example, the maize crop requires about 100 mm of water per month during its growing season, while beans need about 50 mm of water per month (Keller, 2013).

Land Degradation

Land is a fundamental factor in agricultural production, but is susceptible to degradation, which poses a threat to natural assets such as farmland and associated land improvements. This degradation can lead to a decline in the value of physical assets as land becomes less suitable for agriculture. These physical assets include animals, crop quality and quantity, processing facilities and agricultural infrastructure are also at risk from land degradation (Caldecott et al., 2013).

Land degradation in Honduras is primarily caused by the degradation of natural resources, including deforestation, unsuitable agricultural practices, and cattle ranching, leading to the reduction or loss of forest cover, degradation of water sources, and soil erosion. These processes have had detrimental effects on the biological, physical, and chemical properties of the soil, resulting in significant negative environmental impacts that extend beyond agricultural production (Global Enviromental Facility, 2021). Soil structure greatly influences water and air movement, organic matter stability, root growth, seedling establishment, and erosion. Agricultural practices, such as disturbance, compaction, and irrigation, can significantly impact soil structure by breaking up aggregates, filling pore spaces, and dissolving aggregates (Cunningham et al., 2015).

Approximately 72% of the national territory is made up of slopes greater than 15%. Although most of the land is classified as forested (87.7%), approximately 35.6% of the territory has agricultural potential; however, current land use does not match its natural suitability, with agriculture being the predominant use (Interactive Country Fiches, 2023b).

In the country, the vast majority of agricultural soils exhibit a significant level of soil degradation, primarily due to unsustainable production systems, monocultures, and limited use of agricultural technology. The expansion of monoculture and cattle raising is pushing small farmers towards increasingly poor and irregular soils. Most of the nation's soil is poor in nutrients essential for economic yield. Overall, 72% of the soils have been classified as "Low" in organic matter, 66% as "Low" in phosphorus and 51% as "Low" in potassium. The country has large areas that are considered "severely deficient" in nutrients. The departments of Valle, Choluteca, and Atlántida exhibit the highest percentages of soils with low levels of organic matter. Similarly, the departments of Colón, Lempira, Ocotepeque, and Intibucá have the lowest levels of phosphorus in their soils. Lastly, the departments of Gracias a Dios, Colón, and Atlántida show the lowest potassium content (Herrera et al., 2006).

Therefore, there is an increasingly lower average production of key crops such as corn and beans due to the frequent extreme impacts of climate, ongoing soil degradation, and increasing water scarcity caused by rising temperatures, reduced rainfall, and coastal erosion resulting from sea level rise. In addition to this, according to the World Bank, it is estimated that around 40% of the land is degraded, which implies that the soil retains less water (Keller, 2013).

An example of the negative effects of land degradation in agriculture in Honduras is that soil degradation generated by droughts; Two consecutive years of drought starting in 2014 led to a 96% loss of maize yield and 87% loss of bean yield in the country's Dry Corridor (Global Enviromental Facility, 2021). In the case of coffee, rising temperatures are expected to reduce the land available for its cultivation, which is the main product generating foreign exchange, forcing producers to cultivate in elevated areas, between 600 and 1,000 meters, which will increase soil degradation and deforestation in uncultivated areas (USAID, 2017).

An additional case of the economic impact of land degradation can be found in livestock production, the country is experiencing a substantial loss in milk and meat production due to pasture

degradation which is a form of land degradation. Producers estimate that Honduras loses annually about 284,106 metric tons of liquid milk and weight gains equivalent to 48,271 metric tons of live meat because pastures are reaching severe degradation. This represents approximately 48% of the country's annual milk production and 37% of its annual meat production. In economic terms, the monetary value of this decline in milk and meat production amounts to about US$63 million and US$48 million per year, respectively (Holmann et al.).

On the other hand, despite the abundant water resources in some regions of Honduras, many areas still struggle to access an adequate water supply. Surface water sources contribute to 90% of the country's water supply; however, the quality of this water is negatively impacted by extensive deforestation and pollution stemming from agricultural runoff and mining activities (Interactive Country Fiches, 2023b).

Water degradation is a pressing problem, driven by intensified precipitation and extreme weather events. This causes a reduction in water quality and storage capacity due to increased runoff, soil erosion and sedimentation in reservoirs. In addition, rising sea levels cause saltwater intrusion into coastal aquifers, further compromising water quality and availability. To address these challenges and mitigate the negative effects of water degradation on ecosystems and communities, effective water management strategies are crucial (USAID, 2017).

In summary, agriculture-related effects of land degradation encompass various aspects. Deforestation negatively impacts biodiversity and ecosystems. Erosion and decreased soil productivity result in lower agricultural yields and limited production. Water source contamination leads to water scarcity and poor quality, affecting irrigation and crop growth. These factors contribute to subsistence farming, food shortages, insecurity, malnutrition, and increased vulnerability to disease. Negative impacts on agriculture also contribute to unemployment, low income, and poverty, ultimately reducing the quality of life (Interactive Country Fiches, 2023b).

Due to the aforementioned, it is important that the soil is in good condition; when this is the case, it has a well-organized structure that facilitates root penetration, gas exchange and easy absorption of precipitation. The greater the absorption of precipitation, the lesser the incidence of erosion. Erosion becomes evident when the soil is degraded. A degraded soil loses its ability to effectively adsorb precipitation, leading to increased runoff and erosion (Hellin, 2003).

Increased Risk of Agricultural Diseases, Viruses, and Pests

Worldwide, agricultural production is being affected due to the attack of pathogens which reduce yields by damaging plantations. Between 26% and 40% of global crop production is lost due to weeds, pests and diseases and this figure could increase considerably if pest management practices are not used (Caldecott et al., 2013).

In the case of Honduras, the production of basic grains is hampered by the variation in the rainy season, the increase in invasive pests, and crop diseases that have spread because of climate change (Berg et al., 2022). For example, in the period after 2016, damage was related to the adverse effects of climate change and the attack of pests and diseases. Among the main agricultural damages, those caused on maize by the budworm (*Spodoptera frugiperda*) and the disease known as asphalt spot (*Phyllachora maydis*) stand out. In the case of beans, the main damages were caused by drought, slugs (*Sarasinula plebeia*) and bean golden yellow mosaic virus (BGYMV). Despite the drought tolerance of millet, yellow aphid (*Metopolophium dirhodu*) affected 97% of the farmers growing sorghum (World Food Programme [WFP], 2016, Page 2).

Another case is that because of pests and excessive humidity during the late season cycle of 2017 (September-November), farmers in the dry corridor obtained 63 percent of the expected maize production, 58 percent for beans, and 50 percent for sorghum. Consequently, the late season harvest failed to replenish the basic grain reserves of households and meet their needs until September 2018 (The World Food Programme [WFP], 2018).

On the other hand, in the coffee sector coffee there is leaf rust, a disease affecting one of Honduras' major cash crops, can cause significant disruptions for farmers. However, the impact of this disease varies depending on the altitude, as the fungus responsible for the damage struggles to reproduce at higher elevations. Therefore, farmers in the same region but at different elevations may experience different effects from the infection (Berg et al., 2022). An example of the significant impact of the rust disease is that foreign exchange earnings from coffee during the 2012-2013 crop season experienced a decline of US$600.0 million, of which US$216 million was specifically attributed to losses caused by the coffee rust disease (Corrales, 2013). Coffee rust is a disease caused by the fungus *Hemileia vastatrix*, which is found in almost all coffee growing regions of the world. This pathogen mainly affects the commercial coffee species, Coffea *arabica* and Coffea *canephora* (Arneson, 2000). Fungi are organisms that grow in favorable conditions of temperature and humidity. In general, they prefer warm and humid environments, where they can find ideal conditions for their development and reproduction. Altered precipitation schedules and higher temperatures have also been discovered to accelerate the onset of infectiousness in coffee plants affected by leaf rust, thereby intensifying the rate of infection and its dissemination (Willis, 2020).

For livestock, climate change will increase susceptibility to disease and the presence of parasites in livestock due to heat stress. According to Sanders et al. (2019), it has been noted that as temperatures increase in tropical and subtropical areas, livestock production will be affected in three main ways. It is stated that higher temperatures can stress animals, resulting in decreased meat and milk productivity, lower reproductive rates, as well as increased mortality rates. In addition, it is argued that higher temperatures increase susceptibility to disease due to weakened immune systems and may contribute to the increased prevalence and distribution of disease in livestock.

Biodiversity Loss and Collapse of Ecosystem Services

Biodiversity, which encompasses the diversity of animals, plants, and microorganisms at various levels, plays a crucial role in sustaining the functioning and structure of ecosystems. Managing

biodiversity in food and agriculture can help maintain or improve ecosystem functions, leading to optimized agricultural production and increased resilience against risks. The presence of diverse components within ecosystems ensures the provision of valuable services, as even seemingly redundant elements can become significant in the face of changes or disruptions (FAO, 2014).

In Honduras, persistent anthropogenic pressures, natural events, and ecosystem fragmentation are leading to the deterioration and decline of biological diversity (MiAmbiente+, 2021). Honduras, with its tropical location and diverse geography, is a country of exceptional biodiversity. Its varied environments, including rainforests, cloud forests, mangroves, savannas, mountains, and coral reefs, create habitats for a vast array of species (Interactive Country Fiches, 2023a).

However, habitat loss and fragmentation due to smallholder farming, illegal logging, cattle farming, large-scale agriculture, and the conversion to monoculture plantations, such as oil palm and coffee pose the primary threat to biodiversity in Honduras. The majority of the forested areas in Honduras have been transformed for cattle farming, agriculture, and urbanization. Furthermore, the livestock production zones have mostly shifted towards African Palm production. By 2050, a decrease of 19.4% in pasture areas and 8.1% in forests is expected as a result of the increased cultivation of African Palm (Sanders et al., 2015).

The continuous expansion of agricultural boundaries has resulted in the fragmentation and depletion of native forest habitats. From 2000 to 2016, approximately 372,856 hectares were deforested, with an annual deforestation rate of 23,304 hectares (Global Enviromental Facility, 2021). As reported by the Regional Environmental Observatory of the Central American Commission for Environment and Development, Honduras has experienced a significant decline in its biodiversity. By 2008, 52% of its biodiversity had already been lost, and if current trends persist, this depletion is projected to reach nearly 60% by 2030. The main factors contributing to this decline are agricultural expansion, particularly the cultivation of monocultures like palm oil, as well as cattle ranching, urban

growth, and the construction of roads and other human infrastructure. These activities pose major challenges to the preservation of biodiversity in Honduras (Interactive Country Fiches, 2023a).

Moreover, there is a loss of protected areas because the local non-governmental organizations responsible for co-managing the reserves and national parks often face financial constraints that hinder their ability to effectively protect these areas. As is the case in other national parks in the country, limited financial resources and lack of institutional support contribute to reducing the effectiveness of protected areas. Many of these areas also suffer from the presence of agricultural and livestock activities, as well as illegal settlements, which further undermine their conservation efforts (Sanders et al., 2015). For example, The Pico Bonito National Park, along with the Texiguat and Nombre de Dios areas, forms a vast forested region spanning over 180,939 hectares in Honduras. This diverse landscape encompasses tropical forests, cloud forests, and pine forests, supporting a wide range of plant and animal species. However, despite its ecological and social significance, the forest faces ongoing threats from deforestation caused by slash-and-burn agriculture, cattle farming, large-scale agriculture, and the expansion of monoculture plantations like oil palms (Forests of the World, 2021).

Oil palm plantations have experienced significant growth in Honduras, expanding from 24,626 hectares in 1985 to 114,244 hectares in 2015. This expansion has led to deforestation of 33,598 hectares and land use changes of 56,019.74 hectares. However, this kind of monoculture production is favored by agricultural policies, while biodiversity conservation is given low priority. Future projections estimate an additional 7,840 hectares of deforestation from oil palm cultivation and 49,490 hectares from cattle ranching. These practices contribute to carbon emissions, land degradation, and pollution of water and soil (Global Enviromental Facility, 2021).

In addition to the above mentioned, the coffee sector is also one of the main responsible for the loss of biodiversity and ecosystems. The impact of climate change is forcing coffee farmers to relocate their farms to higher altitudes, resulting in the deforestation of previously forested regions.

This phenomenon not only contributes to a significant depletion of biodiversity, but also represents a loss of ecological wealth caused by changes in land use. In the main coffee-growing areas, coffee cultivation occupies around half of the agricultural land. The extent of deforestation driven by coffee production in Honduras surpasses that of other leading coffee-producing nations, highlighting the importance of closely monitoring this issue within the industry (Rainforest Alliance, 2022). In Honduras, coffee occupies up to 50% of agricultural land in the main coffee-growing regions. Since 1990, the country has experienced high deforestation, largely driven by coffee cultivation. Forests have declined by 45% and in 2015 covered only 40% of Honduran territory. Coffee has caused a canopy reduction of approximately 20% of the forest area, equivalent to 1.1 million hectares (Bunn et al., 2018).

Moreover, something that exacerbates the problem even more is the negative impacts of climate change. The phenomenon of climate change is compelling coffee farmers to relocate their farms to higher altitudes, resulting in the clearance of previously forested regions. This process of migration is contributing to the loss of biodiversity in a substantial manner (Rainforest Alliance, 2022). Another form of monoculture that has a negative impact on biodiversity in Honduras is pine monoculture. This monoculture indirectly affects biodiversity due to the presence of a pest that destroys these plantations, which represent the majority of forest plantations in the country. Historically, pine forests in Honduras have experienced bark beetle outbreaks due to prolonged periods of drought associated with El Niño. These outbreaks used to have longer cycles, but in the last six decades they have occurred more frequently. These changes have caused negative impacts on the environment. Between 2014 and 2017, an increase in weevil populations was observed in Honduras, resulting in tree deaths in about 23% of the country's 2.2 million hectares of pine (Honduran Agricultural Research Foundation [FHIA], 2023). The loss of vegetation cover causes changes in the physical, chemical, and biological properties of the soil. In addition, there is a risk of land-use conversion where pine trees were once planted, including agricultural crops, livestock raising, and

rural settlements, among others. This contributes to the degradation of water sources, loss of biodiversity, alteration of local atmospheric conditions and the accumulation of dry biomass, which becomes a potential source of fuel for forest fires in the upcoming summer season (Zelaya, 2017).

Therefore, it can be stated that the connection between agriculture and biodiversity is essential, as they rely on each other. Agriculture depends on biodiversity for its advancement, as the diversity of plant and animal species in both natural and cultivated environments play a crucial role in improving crops and livestock. Conversely, if agriculture does not improve, there will be a higher risk of destroying wildlife habitats to accommodate farms, plantations, and ranches (Srivastava et al., 1996). Agricultural production benefits from biodiversity through various aspects, such as soil formation, land productivity, pest and disease control, groundwater regeneration and pollination. Biological elements such as mangroves and coral reefs act as barriers that reduce the risk of natural disasters. Increasing biological diversity on small farms leads to healthier and more productive soils, which have the capacity to sequester greater amounts of carbon, thus representing a valuable cumulative contribution to carbon storage (IFAD, 2021b). An example of the negative effects of biodiversity loss is the loss of ecosystem services such as insect pollination. According to a major study, the value of global food crop production amounted to 1,618 billion euros in 2005. Insect-pollinated crops accounted for €635 billion, or 39% of the total value. The economic value of insect pollination was estimated at 153 billion euros, with fruits, vegetables and edible oils being the most dependent crops. In addition, approximately 9.5 percent of the world's agricultural production for human food is vulnerable to pollinator decline (Caldecott et al., 2013). This implies that if the habitat of insects is destroyed, they will no longer be able to perform their crucial pollination tasks, resulting in significant losses in the agricultural sector. The loss of floral resources is a fundamental element affecting the availability of pollinators. The alteration of the environment, caused by deforestation and agricultural practices such as monocultures, has had a negative effect on the availability and diversity of energy resources, such as pollen and nectar, as well as nesting and sheltering sites. This circumstance could

cause the migration of wild pollinators to areas where they can find the resources necessary for their survival or, in the worst case, cause their death, which could explain the decline of pollinators (Sosenski & Domínguez, 2018).

In conclusion, smallholder agriculture, livestock farming, and illegal logging are major factors in the conversion of protected areas into monocultures, resulting in biodiversity loss. Moreover, the detrimental effects of the bark beetle pest, worsened by the negative impacts of the El Niño phenomenon, further exacerbate the issue by causing the decline of pine trees, leading to a reduction in forest area, loss of biodiversity, and degradation of ecosystem services. These negative consequences directly impact soil productivity, water quality, and pollination processes, ultimately resulting in limitations to agricultural productivity.

Phosphate Scarcity in the Middle and Long Term

Phosphorus plays a crucial role in promoting crop growth, and it is essential for food production. To ensure optimal crop yields, modern agriculture heavily relies on continuous access to chemical fertilizers that contain phosphorus obtained from phosphate rocks (Cooper et al., 2011). Approximately 90% of the phosphate rock mined worldwide is used in agriculture and food production, raising concerns about how long these reserves will last before their depletion becomes a major problem (Columbia Climate School, 2013).

There is a deficiency of phosphorus worldwide. This deficiency is prevalent in approximately 70% of globally cultivated land. As a result, phosphorus nutrition has become a high-priority research area to enhance vegetative growth and crop productivity (López-Arredondo et al., 2014). Furthermore, there is a concerning lack of research and effective governance at global or national scales when it comes to ensuring the future availability and accessibility of phosphorus, a vital global resource. The world heavily relies on phosphate rock, but this resource is finite and facing increasing scarcity, high costs, and geopolitical tensions (Cordell & White, 2015). Phosphate rock is highly concentrated in six countries: Morocco, China, Algeria, Syria, Jordan, and South Africa, which together

hold about 90% of the world's total remaining reserves. Between them, Morocco holds a significant share, with 74% of the reserves under its control. Moroccan dominance of phosphate rock reserves is expected to increase to 80-90% by 2030 (Cordell & Neset, 2014). One of the problems is phosphate rock prices, since there is less and less of this resource and the demand for phosphorus is increasing to maximize agricultural production and satisfy a growing world population.

Moreover, phosphate extraction is set to peak by 2030, creating a scenario where demand for phosphorus exceeds supply. Economically recoverable reserves of phosphate rock currently stand at 15 billion tons, with an annual extraction rate of about 167 million tons. At the current rate of extraction, lasting around 50 years, but with a 3% annual increase, the reserves would last less than 45 years. This highlights the need for sustainable management and alternative strategies to ensure future phosphorus availability (Bruijne et al., 2009).

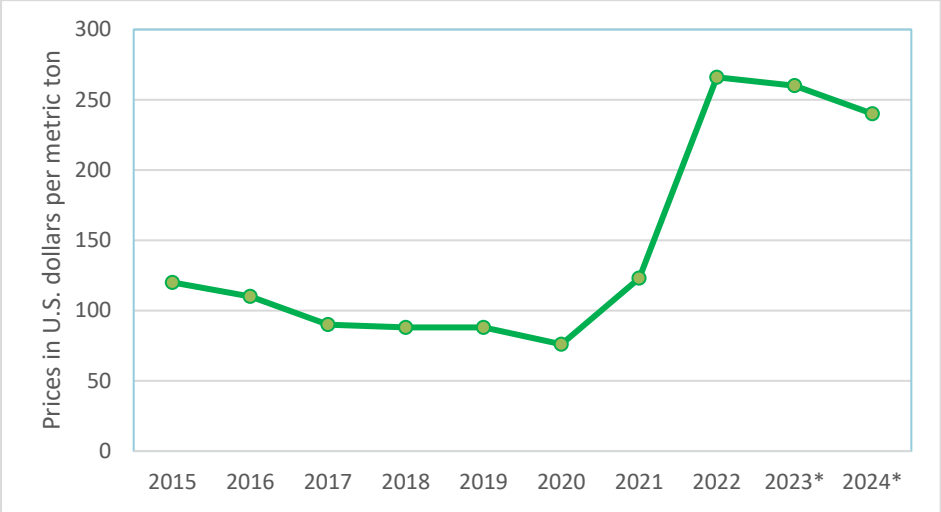
The main challenge lies in the fact that the available amount of usable phosphate rock is insufficient to adequately sustain current levels of food security, with only around 440 million tons being usable. The projected cost of a commonly used fertilizer, DAP, over the period of 2020-2050, would amount to approximately $130 billion ± $25 billion for the agricultural sector. Moreover, additional expenses like transportation and taxes could further drive up the farm-gate price, potentially reaching two to five times higher than the market price. This is a major obstacle for agriculture, which can turn it into a stranded asset (Magnone et al., 2022).

There is already a history of out-of-market price increases for phosphorus. The global food crisis of 2007-2008 saw a 400% increase in the prices of phosphate rock and fertilizers, leading to farmer riots and fatalities in phosphate-dependent countries like India. Since then, high fertilizer prices have remained a challenge for agricultural productivity. The average price per ton of diammonium phosphate (DAP) has been 4.60 ± 1.28 times higher than phosphate rock, while Triple Superphosphate (TSP) has been 3.86 ± 1.02 times higher. Furthermore, there has been a recent surge in phosphate rock prices, increasing by 250% between April 2021 and April 2022 (Alewell et al., 2020;

Magnone et al., 2022). Honduras, as a phosphate-importing country, likely faced similar challenges as India. The following figure depicts the change in phosphate rock prices worldwide since 2015 and includes forecasts for 2023 and 2024.

Figure 2

Phosphate rock price from 2015 to 2022 with a forecast for 2023 and 2024.



Note. Taken from Statista (2023)

The graph shows how there was a reduction in the price of phosphate rock from 2015 to 2020 of up to US$44 per metric ton. However, from 2021 onwards prices rose dramatically to peak in 2022 with a price of U.S. 266 dollars. A slight price decrease is expected for 2023 and 2024. This means that if fertilizers are much more expensive than phosphate rock and this resource rises in price, fertilizers will become increasingly expensive and difficult to acquire, especially for small farmers.

In 2021, Honduras purchased $34.5 million worth of Diammonium Phosphate in packages exceeding 10 kg, ranking as the 39th largest importer of such product worldwide. During the same year, Diammonium Phosphate in packages exceeding 10 kg stood as the 75th most imported item in Honduras. Honduras primarily imported Ammonium Phosphate in packages exceeding 10 kg from the following countries: United States ($18.2 million), China ($8.5 million), Turkey ($6.24 million), El Salvador ($1.05 million), and Russia ($296,000) (The Observatory of Economic Complexity [OEC], 2022).

It is important to emphasize that phosphorus availability is one of the main factors limiting the achievement of food security in many tropical countries (Magnone et al., 2022). Tropical and subtropical soils are mainly acidic and generally very deficient in phosphorus. Nevertheless, most of these soils have a high phosphate adsorption potential (International Atomic Energy Agency, 2002). This issue is primarily observed due to soil erosion caused by heavy rainfall, steep slopes, and poor practices conditions. In the case of Honduras, climate change is the main cause of phosphorus scarcity, since rainfall related to this phenomenon is responsible for this loss (Alewell et al., 2020).

Conclusions

The findings support the argument that agriculture is becoming a "stranded asset" in Honduras, as each of the physical drivers significantly affects the profitability of agricultural activities. However, the agricultural sector, including both public and private stakeholders, is constrained by serious political and economic constraints, resulting in a state of overall weakness (Salomón, 2022).

Due to the political difficulties faced by the country, international aid plays a vital role in supporting the improvement of sustainable agronomic practices. For example, Honduras received support in 2021 from the International Fund for Agricultural Development (IFAD), a UN agency dedicated to rural development, and its collaboration with the government has facilitated the country's access to funding from the Green Climate Fund (GCF). The objective of this funding is to promote small-scale climate-smart agriculture in Honduras. The planned actions were climate resilient infrastructures such as water harvesting, irrigation systems and rural roads. In addition, nature-based solutions were promoted, encompassing environmental services, climate early warning systems, resilient agricultural practices, and territorial planning (IFAD, 2021a).

Among the physical factors that affect profitability in agriculture, climate change is the most pressing, given that Honduras is a country with infrastructure problems and, in general, high levels of poverty. Moreover, even though several of these factors do not directly impact agriculture, there is a lack of data on the economic repercussions that these factors may have for farmers. However, it is important to highlight that not all crops, regions, or production systems are equally vulnerable to becoming stranded assets; some are more vulnerable than others.

Stranded assets mostly affect smallholder farmers, who are the main group in the sector and are engaged in subsistence farming. Small farmers lack the technology, sustainable practices, and economic capacity to cope with the challenges of the blockade on their own.

Therefore, it is important to develop a more resilient agricultural sector that would involve substantial transition costs, which the sector could not bear. This is mainly because people are not

disposed to pay more for sustainable produced crops, especially staple crops. This inference is supported by data from the FAO, which reveals that around 4.9 million people in Honduras experience "food insecurity," with 1.5 million individuals suffering from undernourishment and many others lacking the resources required to maintain a nutritious diet (SWI swissinfo.ch, 2023).

Recommendations

In order to mitigate the stranding risks, the government should adopt effective (fiscal and non-fiscal) policies aimed at promoting investments in sustainable technologies, thereby enhancing the sector's resilience. Tax breaks on agricultural machinery and precision agriculture technologies such as drones, GPS, moisture sensors, etc. This could make it easier for enterprises to assume the costs of this transition to a sustainable agriculture.

Regarding non-fiscal incentives could include technical support such as training farmers and providing information and technology for small farmers. For example, FAO carried out a series of incentives in 15 underdeveloped countries that it describes as successful for the transition to sustainable agriculture. One of these incentives was learning-by-doing with smallholder farmers. do this, the public sector formed a partnership with international organizations, universities, and research institutes to create locally adapted and ecosystem-specific training plans for sustainable agriculture. These innovative and participatory approaches and make applied research more effective and inclusive (FAO, 2016).

Another incentive is the provision of new technologies to make production systems more efficient and sustainable. For example, the use of technologies such as precision agriculture to determine soil characteristics and optimize nutrient utilization. This can help close yield gaps and increase production without expanding agricultural land, reducing deforestation, greenhouse gas emissions as well as soil and water pollution. In addition, precision agriculture plays a crucial role in facilitating frequent crop monitoring through the use of drones and remote sensing techniques.

To foster innovation and research, agricultural the sector should consider adopting a Triple Helix model (Erosa, 2012), which would provide a comprehensive platform for collaboration among academia, industry, and government. The union of forces is crucial in implementing new sustainable agricultural practices. These three entities assume distinct yet interconnected functions within the process of innovation. Universities contribute by generating fresh knowledge through research,

businesses transform this knowledge into tangible offerings, and government agencies foster an innovative atmosphere through conducive policies and frameworks (Krneta & Leburiæ, 2007).

The implementation of the Triple Helix Model in agriculture offers numerous advantages. It drives increased innovation by leveraging the expertise of diverse actors, resulting in the development of efficient and sustainable agricultural products and processes. The model also improves productivity by providing businesses with access to new knowledge and resources, leading to the adoption of more effective production methods and higher-quality outputs. Moreover, it enhances the sector's competitiveness by aligning with market demands and supporting the creation of innovative products and services. Lastly, the model promotes sustainable development by encouraging the adoption of environmentally friendly technologies and practices in agriculture (Ferreira et al., 2016). Implementing these policies can contribute to the resilience of the agricultural sector.

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