Katherine Monroe
Princeton High School
Princeton, NJ, USA
Indonesia, Deforestation

Larvae on Islands of Lava: Utilizing Insect Agriculture to Restore Indonesia's Biodiversity and Stimulate Economic Growth

Deforestation due to the palm oil industry has caused the tragic loss of much of Indonesia's verdant lowland rainforests, some of which are nearly 140 million years old (Leeder et al.). This has come at the cost of human health, livelihood, and devastating environmental consequences. This paper proposes insect agriculture as a means of replacing palm oil and helping to reduce the damage done by deforestation.

With a population of 273.52 million people (in 2020) and a growth rate of 1.065%, Indonesia is the world's fourth most populous country (World Bank, 2020). Of this population, 56.6% are urban, while 43.4% are rural (World Bank). Indonesia is a constitutional democratic republic and its three branches of government are headed by current president Joko Widodo (Embassy of Indonesia). Roughly 33% of Indonesia's land is agricultural (cultivated) land (World Bank, 2018). Major Indonesian industries include fishing, timber, and mining of oil, natural gas, and coal. Important crops include cassava, rice, coffee, and rubber. (Embassy of Indonesia, Frederick). Notably, 20% of Indonesia's export earnings come from the palm oil industry—also a major employment sector. Palm oil makes up 40% of global demand for vegetable oil, and Indonesia is the world's second-largest producer (Meijaard et al., 2020; Wijaya, 2019). Small family subsistence farms of about 0.6 hectares (the size of 1.5 football fields) make up 93% of Indonesia's farms, producing the majority of staple crops and cash crops (FAO, 2018).

The average household size is 3.9 people (Esri, 2021). Rural homes are often constructed using natural materials like wood, woven bamboo, and dried palm fiber; in urban settings, cement, tile, wood, plaster, and shingles are used (Encyclopedia Britannica). Rice is a staple food, forming the basis of most meals. Traditional Indonesian food is rich in spices and side dishes often consist of vegetables and meat (chicken, beef, fish). Most Indonesians obtain food from supermarkets and retail stores (Dyck et al., 2012). Food preparation often involves frying, grilling, and steaming (Wijaya). The Indonesian diet is high in complex carbohydrates, monounsaturated fatty acids, and fiber. The prevalence of health issues relating to diet and food availability should be noted; 20% of elementary school-aged children are overweight or obese, while two million children under the age of 5 suffer from severe acute malnutrition (UNICEF).

Indonesia employs 38.22 million people in agriculture, forestry, hunting, and fisheries (Statista, 2020). The average monthly wage is roughly 2.86 million Indonesian rupiahs (US$199.69, or US$2396.28/year) (Statista). While rates of schooling and college enrollment are growing, literacy rates are around 45%—much lower than neighboring countries—and only about 9% of Indonesians are college-educated (Dilas et. al, 2019). Nearly 10% of Indonesians do not have access to toilets, contributing to major sanitation and water quality issues (UNICEF). Water is often contaminated and contributes to disease. At the same time, access to electricity is widespread (World Bank), although low-income families are challenged by the growing wealth gap and poor infrastructure (OXFAM). Around 7% of the population

cannot meet dietary requirements due to the high price of food (WFP). Indonesia's Universal Health Coverage index is 59/100, meaning that it still faces "major challenges" in providing essential health services (UNSDSN, 2017).

Indonesia comprises over 17,000 islands and spans coastal plains, swamps, coral reefs, and mountainous regions with active volcanoes. An equatorial country, most of Indonesia is warm year-round, with average temperatures of 23-28ºC. Seasons are defined by monsoon rains; the dry season is June to December, and the rainy season is December to March. Indonesia's expansive rainforests have great biodiversity and are home to 10% of the world's plant species and more mammal species (515) than any other country, many of which are critically endangered, such as the Sumatran tiger, the orangutan, and the Javan rhinoceros (Frederick, 2011, RAN).

Deforestation is among the most calamitous environmental issues facing Indonesia today. Since 1990, Indonesia has lost almost 25% of its forests (Sheldon and Sankaran, 2017). Due to the demand for palm oil, large swaths of land have been cleared to make space for oil palm plantations. Between 1972 and 2015, up to 50% of deforestation on the island of Borneo can be attributed to palm oil production (Meijaard et al.). Palm oil is an incredibly lucrative industry, and it can promote economic growth (Meijaard et al.), yet the negative environmental impacts are numerous. One common practice involves intentionally burning forests to clear space for oil palm. This results in forest fires that pollute the air with smoke and toxins. In neighboring Singapore, one study indicates that Indonesian forest fires caused an increase in respiratory health problems, which are especially dangerous for infants and the elderly (Sheldon and Sankaran). Decreases in water quality for humans and aquatic life have also been observed due to runoff from plantations that contains harmful fertilizers and pesticides (Meijaard et al.).

Studies have found that deforestation and oil palm farming contribute to climate change by producing greenhouse gases and reducing the carbon-neutralizing capacity of previously forested areas (Meijaard et al.). In Borneo, shrinking forested area has likely caused reduced rainfall and hotter temperatures, which can threaten wildlife and increase the risk of fires and droughts (Meijaard et al.). Oil palm plantations also cause ecosystem disruption and habitat loss. Oil palm is a monoculture crop; plantations grow only oil palms, which are non-native and potentially invasive (Meijaard et al.). Oil palm plantations may contain less than 1% of the plant diversity found in natural forests and a 47-90% decrease in mammal species diversity was observed (Meijaard et al.).

Oil palm farming has also caused social issues and reduced quality of life. While 67.2% of oil palm plantations are industrial-scale, the rest are smallholders—farms of less than 2 hectares managed by local farmers. Smallholders are often trapped in poverty and are vulnerable to unfair treatment in the supply chain (WIEGO). The domination of the industry by large, profit-focused national and international companies raises concerns for the wellbeing of local communities. Oil palm farming has led to land conflicts, labor exploitation, and economic inequality (Meijaard et al.). An analysis of land conflicts related to Indonesian oil palm plantations found that they cost local households over US$3,000 (Rp43,034,250) per year (Zakaria et al., 2018).

While most effects of deforestation are more keenly felt by rural populations, other effects such as pollution, wealth inequality, and climate change affect urban populations as well. Finally, deforestation

has devastating impacts on Indonesia's indigenous peoples, such as the Dayak and Orang Rimba peoples (from the islands of Borneo and Sumatra, respectively) (HRW, 2019). The palm oil industry has mostly ignored indigeneous rights, resulting in the loss of livelihood of many indigenous Indonesians. Many are now left without forested areas for foraging and without land to farm and sustain themselves (HRW).

Though Indonesia has recently made efforts to protect "high biomass" natural forests, many still face illegal logging (Chakrabarti, 2021). Deforestation rates have dropped in the past year, but experts predict a rise due to government inaction (Jong, 2021). There is also a movement toward "certified sustainable" palm oil production. In theory, "certified" growers are required to conserve biodiversity and protect rare species (Gatti and Velichevskaya, 2020). However, researchers have found that many certified plantations encroach on habitats of endangered species (Gatti and Velichevskaya). In addition, these plantations remain biodiversity "deserts" that fragment previously-connected habitat and are only considered "sustainable" because the land was cleared years ago rather than recently (Gatti and Velichevskaya).

Reducing deforestation is a clear solution to these environmental problems. However, palm oil is widely used, making this a very difficult undertaking (WWF, 2018). Though perhaps unconventional, one potential alternative to palm oil is insect oil. Recently, insect rearing has become more widespread. The mealworm (*Tenebrio molitor*) and the black soldier fly (*Hermetia illucens*, hereafter referred to as BSF) show particular promise for their variety of applications. Both organisms are suited to Indonesia's tropical climate and can be cheaply and easily raised on a diet of organic waste, such as excess fruits, vegetables, and manure (Son et al., 2020; da Silva, 2019; Henry et al., 2018).

Insects can be used to produce oil which could replace palm oil in many products ranging from cooking oil to cosmetics to biofuels (WWF). Palm oil is commonly used in cooking and food products, making it essential to test the safety and practicality of insect oil in these same uses. Numerous studies show that both mealworm oil and BSF oil are safe for human and animal consumption (Henry et al.; Son et al.; Tzompa-Sosa et al., 2021; Rawski et al., 2020). Insect oil closely resembles certain vegetable oils, as they share lauric acid content and similar fatty acid composition (Enviroflight, Son et al.). Insects can be dried and eaten, or ground into powder and added to food. Studies show that insects are high in protein and in some cases have a higher nutritional value than other meat (Payne et al., 2015). Mealworm oil has successfully been used as a partial replacement for butter in baked goods and could fully replace vegetable oil without affecting taste after undergoing a deodorizing process (Tzompa-Sosa et al.). In some Indonesian cultures, the diet already includes insects such as the Sago maggot, the Nyale worm, and grasshoppers (Zul Astri, 2016). It should be noted that Indonesia is a majority Muslim country, and under some interpretations insects are not considered *halal* (permissible) to eat. In such a case, mealworms and BSF could be used as feed for livestock (particularly fish and chickens), and insect oil could be sold through export markets. Studies have found that fish can be raised on 30-50% insect meal diets, which promoted beneficial anti-inflammatory and anti-parasite activity in the fish (Henry et al.).

Another application of insect rearing is the potential use of insect frass (excrement) as fertilizer. Frass contains essential nutrients for plant growth that are found in commercial fertilizers, including nitrogen, phosphorus, potassium, and calcium (Houben et al., 2020). Also, frass contains a polysaccharide called chitin, which research suggests may increase plant growth, reduce plant pathogens and pests, and increase beneficial microbes (Sharp, 2013). Use of frass may activate genes that produce chitinase, an enzyme

implicated in disease resistance against fungi (Chen et al., 2018). The use of frass could promote beneficial microbe activity and help repair soil degradation and biodiversity loss from deforestation and oil palm farming. The use of insect frass as fertilizer could also combat malnutrition by increasing crop yields.

While insect rearing and insect oil production could be carried out by industrial companies, smallholders or local farmers could also raise insects at little cost and effort, then use or sell the insect products themselves. The process of converting insects into oil is relatively straightforward; larvae can be dried in an oven and oil can then be extracted using a mechanical press (Enviroflight).

Combined with the low cost and ease of raising insects, their numerous applications make insect rearing very sustainable. Implementing insect agriculture could be managed at a local level by native Indonesians and smallholders. While it could be beneficial to have a non-profit organization purchase materials like oil presses, these inputs are relatively inexpensive and the profits generated by insect products such as oil and frass, as well as a reduced dependence on commercial animal feeds, would quickly pay for themselves. The project could be community-driven, with little interference from companies or government organizations. Nonetheless, the government could implement greater restrictions on palm oil production and deforestation while also promoting and/or subsidizing the practice of insect rearing.

Insect agriculture holds great promise for helping restore the land and biodiversity loss caused by oil palm farming in Indonesia. This inexpensive practice could help lift vulnerable communities out of poverty by allowing them to sustain themselves while also producing useful products like insect oil, animal feed, and frass fertilizer. Though deforestation may have shrouded Indonesia's forests in uncertainty, bugs have the potential to bring about a brighter future.

Bibliography

Access to electricity (% of population) - Indonesia | Data. (2019). World Bank. https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=ID

Agricultural land (sq. km) - Indonesia | Data. (2018). Data.worldbank.org. https://data.worldbank.org/indicator/AG.LND.AGRI.K2?locations=ID

Average Household Size in Indonesia. (2021). Arcgis.com. https://www.arcgis.com/home/item.html?id=7d1b66f2aa374167a337c6b0e386fc80#:~:text=Description-

Chakrabarti, A. (2021). Deforestation and infant mortality: Evidence from Indonesia. *Economics & Human Biology*, *40*, 100943. https://doi.org/10.1016/j.ehb.2020.100943

Chen, J., Piao, Y., Liu, Y., Li, X., & Piao, Z. (2018). Genome-wide identification and expression analysis of chitinase gene family in Brassica rapa reveals its role in clubroot resistance. *Plant Science*, *270*, 257–267. https://doi.org/10.1016/j.plantsci.2018.02.017

da Silva, G. D. P., & Hesselberg, T. (2019). A Review of the Use of Black Soldier Fly Larvae, Hermetia illucens (Diptera: Stratiomyidae), to Compost Organic Waste in Tropical Regions. *Neotropical Entomology*. https://doi.org/10.1007/s13744-019-00719-z

Dilas, D. B. (2019, May 23). *Education in Indonesia*. WENR. https://wenr.wes.org/2019/03/education-in-indonesia-2

Dyck, J., Woolverton, A., & Rangkuti, F. (2012). *Indonesia's Modern Retail Sector Interaction With Changing Food Consumption and Trade Patterns*. https://www.ers.usda.gov/webdocs/publications/44684/28836_eib97_1_.pdf?v=0

EnviroOil™ | Products | Producer of Black Soldier Fly Larvae | ENVIROFLIGHT. (n.d.). Www.enviroflight.net. Retrieved February 13, 2022, from https://www.enviroflight.net/products/enviro-oil

Frederick, W. H., & Worden, R. L. (1993). *Indonesia : a country study*. Federal Research Division, Library Of Congress.

Gatti, R. C., & Velichevskaya, A. (2020). Certified "sustainable" palm oil took the place of endangered Bornean and Sumatran large mammals habitat and tropical forests in the last 30 years. *Science of the Total Environment*, *742*, 140712. https://doi.org/10.1016/j.scitotenv.2020.140712

Government – Embassy of the Republic of Indonesia | Washington D.C. (n.d.). Embassy of the Republic of Indonesia. https://www.embassyofindonesia.org/government/

Henry, M. A., Gasco, L., Chatzifotis, S., & Piccolo, G. (2018). Does dietary insect meal affect the fish immune system? The case of mealworm, Tenebrio molitor on European sea bass, Dicentrarchus labrax. *Developmental & Comparative Immunology*, *81*, 204–209. https://doi.org/10.1016/j.dci.2017.12.002

Houben, D., Daoulas, G., Faucon, M.-P., & Dulaurent, A.-M. (2020). Potential use of mealworm frass as a fertilizer: Impact on crop growth and soil properties. *Scientific Reports*, *10*(1), 4659. https://doi.org/10.1038/s41598-020-61765-x

Human Rights Watch. (2019, September 22). *"When We Lost the Forest, We Lost Everything."* Human Rights Watch. https://www.hrw.org/report/2019/09/23/when-we-lost-forest-we-lost-everything/oil-palm-plantations-and-rights-violations

Impacts on Newborns | State of Global Air. (n.d.). Www.stateofglobalair.org. https://www.stateofglobalair.org/health/newborns#:~:text=Air%20pollution%20is%20linked%20with

Indonesia - Housing. (2022). Encyclopedia Britannica. https://www.britannica.com/place/Indonesia/Housing

Indonesia - small family farms country factsheet. (2018). https://www.fao.org/3/I8881EN/i8881en.pdf

Indonesia | World Food Programme. (n.d.). Www.wfp.org. https://www.wfp.org/countries/indonesia

Indonesia: Country Profile. (2020). World Bank. https://databank.worldbank.org/views/reports/reportwidget.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=en&country=IDN

Indonesia: employment numbers by industry 2020. (2021, October 4). Statista. https://www.statista.com/statistics/994498/employment-numbers-by-industry-indonesia/#statisticContainer

Indonesia's Rainforests: Biodiversity and Endangered Species. (n.d.). Rainforest Action Network. Retrieved February 13, 2022, from https://www.ran.org/indonesia_s_rainforests_biodiversity_and_endangered_species/#:~:text=Indonesia%27s%20 rainforests%20are%20 home%20to

Inequality in Indonesia: millions kept in poverty | Oxfam International. (2018, April 17). Oxfam International. https://www.oxfam.org/en/inequality-indonesia-millions-kept-poverty

Jong, H. N. (2021, March 9). *Deforestation in Indonesia hits record low, but experts fear a rebound*. Mongabay Environmental News. https://news.mongabay.com/2021/03/2021-deforestation-in-indonesia-hits-record-low-but-experts-fear-a-rebound/

Leeder, A., Brown, A., Coleman, G., Digby, B., Owen, G., & Davis, V. (2016). *WJEC GCSE Geography Second*. Hodder Education.

Meijaard, E., Brooks, T. M., Carlson, K. M., Slade, E. M., Garcia-Ulloa, J., Gaveau, D. L. A., Lee, J. S. H., Santika, T., Juffe-Bignoli, D., Struebig, M. J., Wich, S. A., Ancrenaz, M., Koh, L. P., Zamira, N., Abrams, J. F., Prins, H. H. T., Sendashonga, C. N., Murdiyarso, D., Furumo, P. R., & Macfarlane, N. (2020). The environmental impacts of palm oil in context. *Nature Plants*, *6*(12), 1418–1426. https://doi.org/10.1038/s41477-020-00813-w

Nutrition. (n.d.). UNICEF. https://www.unicef.org/indonesia/nutrition

Payne, C. L. R., Scarborough, P., Rayner, M., & Nonaka, K. (2015). Are edible insects more or less "healthy" than commonly consumed meats? A comparison using two nutrient profiling models developed to combat over- and undernutrition. *European Journal of Clinical Nutrition*, *70*(3), 285–291. https://doi.org/10.1038/ejcn.2015.149

Rawski, M., Mazurkiewicz, J., Kierończyk, B., & Józefiak, D. (2020). Black Soldier Fly Full-Fat Larvae Meal as an Alternative to Fish Meal and Fish Oil in Siberian Sturgeon Nutrition: The Effects on Physical Properties of the Feed, Animal Growth Performance, and Feed Acceptance and Utilization. *Animals*, *10*(11), 2119. https://doi.org/10.3390/ani10112119

Sharp, R. (2013). A Review of the Applications of Chitin and Its Derivatives in Agriculture to Modify Plant-Microbial Interactions and Improve Crop Yields. *Agronomy*, *3*(4), 757–793. https://doi.org/10.3390/agronomy3040757

Sheldon, T. L., & Sankaran, C. (2017). The Impact of Indonesian Forest Fires on Singaporean Pollution and Health. *The American Economic Review*, *107*(5), 526–529. https://www.jstor.org/stable/44250454

Smallholder Farmers | WIEGO. (n.d.). Www.wiego.org. https://www.wiego.org/informal-economy/occupational-groups/smallholder-farmers

Son, Y.-J., Choi, S. Y., Hwang, I.-K., Nho, C. W., & Kim, S. H. (2020). Could Defatted Mealworm (Tenebrio molitor) and Mealworm Oil Be Used as Food Ingredients? *Foods*, *9*(1), 40. https://doi.org/10.3390/foods9010040

Sustainable Development Report 2021. (2017). Sustainable Development Report; United Nations. https://dashboards.sdgindex.org/map/indicators/universal-health-coverage-uhc-index-of-service-coverage

Tzompa-Sosa, D. A., Dewettinck, K., Gellynck, X., & Schouteten, J. J. (2021). Replacing vegetable oil by insect oil in food products: Effect of deodorization on the sensory evaluation. *Food Research International*, *141*, 110140. https://doi.org/10.1016/j.foodres.2021.110140

Urban population (% of total population) - Indonesia | Data. (2020). World Bank. https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=ID

Water, sanitation and hygiene. (2017). UNICEF. https://www.unicef.org/indonesia/water-sanitation-and-hygiene

Wijaya, S. (2019). Indonesian food culture mapping: a starter contribution to promote Indonesian culinary tourism. *Journal of Ethnic Foods*, *6*(1). https://doi.org/10.1186/s42779-019-0009-3

WWF. (2018, November 12). *8 Things to Know about Palm Oil*. WWF; WWF. https://www.wwf.org.uk/updates/8-things-know-about-palm-oil

Zakaria, R. Y., Pradiptyo, R., Iswari, P., & Wibisana, P. S. (2018). *The cost of and natural resources conflict: a community perspective*. https://www.conflictresolutionunit.id/wp-content/uploads/2019/03/Summary-Biaya-Konflik-20180428.pdf

Zul Astri, M. (2016, June 3). *Insects foods in Indonesia - BCFN Foundation*. Barilla Center for Food and Nutrition. https://www.barillacfn.com/en/magazine/food-and-society/insects-foods-in-indonesia/