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Impacts of Invasive Species on Agriculture in Hawaii

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Introduction

Invasive species pose significant threats to global agriculture, according to a study on impacts of 1300 invasive species on agriculture in 124 countries [1]. Invasive species dramatically decreased crop production and can be a major factor affecting food security [2]. In the United States alone, the losses in agricultural and forest production from invasive insects and pathogens have been estimated about $40 billion per year [3]. The United States as one of the four large agricultural producers in the world could experience a serious cost from further species invasion. The state of Hawaii makes up less than one percent of the United States land area but over 40 percent of the country's threatened and endangered plant species are found in Hawaii. Hawaii is known as the endangered species capital of the world, with 90 percent of the 1,400 Hawaiian endemic plant species are found nowhere else in the world according to the Hawaii State Department of Land and Natural Resources.

As one of the most isolated archipelagos in the world, Hawaii islands are vulnerable to invasive species. The entire island chain of Hawaii has been devastated by invasive insects, plants, hoofed animals and other pests in almost all agricultural and forest ecosystems [4,5]. Among at least 5300 alien species already established in Hawaii approximately 300-500 species are estimated to be invasive [6,7]. In addition, the introduction of exotic species to the islands increased exponentially over the past several decades [7,8]. With the alarming rate of exotic species introduction, the numbers of invasive species naturalized to the islands are predicted to increase remarkably though only a small percent of introduced species ever become invasive. The growing invasive species crisis poses significant risks to Hawaii's tourism and agriculture-based economy.

For hundreds of years before the arrival of Europeans led by British explorer James Cook, Hawaiians have been associated with ecological agriculture since their settlement. They followed the land divisions, called ahupua'a. Each ahupua'a was an area of land running from the uplands to the sea, following the natural boundaries of the watershed created pie-shaped slices of land. The Hawaiian Islands are suitable for agriculture under a mild climate allowing a year-round growing season with the average high temperature of 25°C in July and the low temperature of 21°C in January. The native Hawaiians produced a wide array of agricultural products, including banana, taro, sweet potatoes, ginger, sugar, coconut, and some uniquely Polynesian crops. From 1840s to 1980s, Sugar Cane and Pineapple plantations were the largest employers in Hawaii and the most valuable agricultural industry. Due to the shifting political alliances on food market, increasing labor cost and thriving tourism industry, land used for agriculture has declined by 68 percent from 1980 to 2017 according to a report by The Washington Post.

After the abandoned sugar cane and pineapple plantations, how to keep Hawaii's extraordinary lands in active agriculture is a great challenge. Besides the high cost of land, irrigation, workers and transportation, a significant modern challenge to farming on the land in Hawaii is the rapidly expanding invasive species which exert severe negative impacts on agriculture [9]. The following are the major problems caused by invasive species in almost all branches of agriculture in Hawaii.

Habitat loss The Hawaiian Islands possesses a wide range of habitats, from wet forests to extremely dry coastal grasslands. The habitats are characterized by high levels of endemism in both native animals and plants, with over 10,000 species found nowhere else in the world. Native biodiversity is not only important to natural ecosystems but also to agricultural practices. Hawaii's native wildlife and their associated ecosystems provide essential goods and services to residents such as water quality, soil conservation, carbon storage, and climate regulation [10,11]. With the introduction of invasive species and more recently development, many of native habitats have been fragmented or completely lost. For example, 90 percent of Hawaii's dryland habitat, 61 percent of the mesic habitat, and 42 percent of wetlands have been estimated to be lost since the late 18th century [4].

Today, native vegetation occurs over less than 40 percent of the land area of Hawaii. With only 0.2 percent of the country's total landmass, Hawaii has the highest number of endangered species in the United States accounting for more than 30 percent of the total species listed as endangered in the country [12]. Almost all the native bird or plant species in Hawaii have no defense mechanisms due to the lack of predators or large herbivores during their evolutionary processes and ecological interactions. Invasive predators such as rats, mongoose, and feral cats' prey on native birds. At higher elevations, feral cats are the most important predators of endangered Hawaiian birds including ground-nesting waterfowl [13] and tree-nesting passerines [14]. The mongooses are native to India and were intentionally introduced to Hawaii in 1883 to control rats in sugarcane fields. Mongoose and rats consume a wide variety of food types including seabird, water bird, bird eggs, chicks, and even adults, sea turtle eggs and hatchlings. Invasive ants in Hawaii can also have great impacts on habitat of native invertebrates and birds, especially seabirds. Ant colonies can reach incredibly high densities on the islands and reduce native insect food available for birds and exclude native plant and crop pollinators from nectar sources, especially native bees and moths [15,16].

Alteration of Hawaiian ecosystems Invasive species can change abiotic and abiotic components of an environment in many ways based on how they interact with their new surroundings. These interactions can reduce the amount of resources for native species, directly or indirectly affect food-web structures, and thus alter the balanced ecosystems. Some invasive species in Hawaii play a significant role in altering entire ecosystems. For example, strawberry guava and albizzia destroys native forest habitats, reduces the abundance of native plants, and diminishes food resources for native birds. The lack of a diverse understory in dense strawberry guava forests greatly enhances soil erosion and damages watersheds [17,18].

Hybridization of native species with introduced related species can have a large effect on the genetic structure of native species populations. Genetic extinction occurs when population sizes differ immensely [19]. An example of this phenomenon is the hybridization of Hawaii's native duck with introduced mallards. Ungulates such as feral pigs, goats, sheep, and cattle Ungulate populations have played a destructive role in the fragile agricultural ecosystems of Hawaiian Islands. Grazing and rooting damage native vegetation and cause soil erosion and sediment run-off. In addition, invasive mammals together with invasive plants alter island nutrient cycles [17]. Researchers from the Savannah River Ecology Laboratory at the University of Georgia reported that invasive mammals in Hawaii altered island ecosystem nutrient cycles which poses significant impacts on farming and animal husbandry.

Insects & diseases Introduced diseases and insects can dramatically reduce the production of agricultural crops and tree plantations. For example, the Small Hive Beetle (SHB), Native to sub-Saharan Africa and found in Hawaii in 2010, may cause rapid decline of the populations of honeybees, a critically important pollinator of agricultural crops in Hawaii. Invasive species often carry new diseases for crops and native plants and animals. For example, the introduction of mosquitoes to Hawaii has resulted in the spread of avian malaria, a major contributor to population declines and extinctions for many endemic Hawaiian honeycreepers [20]. A new fungal pathogen referred to as "Rapid Ohia Death" (ROD) was identified on Hawaii Island in 2014. ROD is comprised of two pathogens, *Ceratocystis lukuohia* and *Ceratocystis huliohia*, and currently attack and kill Ohia on Hawaii Island. Ohia (Metrosideros polymorpha) is the most abundant native tree in Hawaii islands and Ohia forests provide habitat for countless plants, animals and invertebrates. A significant amount of agriculture and drinking water is from Ohia forests. ROD poses a very serious threat to Hawaii agriculture, forests and natural resources.

Revitalizing Hawaii's Agriculture

Some 90 percent of food in Hawaii is still imported and it deadly needed to revitalize its agriculture to produce agricultural products for the local market efficiently enough to replace most imports. To reach this goal Hawaii Department of Agriculture (HDOA) provides facilitative leadership to both the public and private sectors to develop regenerative and sustainable agriculture.

First, prevention and control of invasive species. Hawaii, the capital of endangered species in the world, is vulnerable to species invasion. Currently Hawaii's agriculture is greatly threatened by increasing invasive species, such pollinator risk and various crop diseases and pathogens. To revitalize its agriculture, local communities, nonprofit organizations, county agencies and educational institutions should work collaboratively to enhance prevention and control of invasive species.

Second, developing sustainable agriculture. The future agricultural systems must be resource conserving, socially supportive, commercially competitive, and environmentally friendly. To develop sustainable agriculture and communities, producing local foods, such as breadfruits, cacao and avocado, and restoring ahupua'a-like management of the land are essential to creating high-value products and protecting the land.

Third, application of high agricultural technology. RBC's Farm 4.0 indicates that coming skill revolution can transform agriculture and the fourth agricultural revolution is underway. For example, advanced technology like autonomous tractors and drone-mounted sensors can transform the traditional way we produce food. Only if applying new technology skills can Hawaii's agriculture develop sustainably by reducing the labor cost which is one of the major buriers of agriculture in Hawaii.

Finally, agritourism. Travel associated with farming is a growing phenomenon. Agritourism includes farm stays, walking

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tours, livestock operations, restaurants serving regional cuisine, agricultural fairs and festivals, etc. Agritourism generates supplemental income and it helps to farm stabilization. Good examples for agritourism in Hawaii are Kona's Uchida Coffee farm and Mauna Loa Macadamia farm.

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