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The Mark of Sugar. Hawai`i's Eco-Industrial Heritage

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Abstract: Hawai`i's eco-industrial heritage is a landscape permanently altered by sugar cane production. Beginning in 1850 American and European-based capitalists drew heavily from global technological advances of the nineteenth century, rapidly exploited the land and water policies of the native Hawaiian government, and set in motion environmental change that eventually increased industrial control over non-sugar cane ecosystems. This article exams the nature-industry exchange which culminated by 1920 in an industrial sugar ecology that dominated landscapes, politics, and social life in Hawai`i.

Industrial agriculture has permanently altered the Hawaiian Islands. At the end of the eighteenth century these islands were a Polynesian chain of chiefdoms based upon irrigated and dryland agriculture. Within a century, the Hawaiian Kingdom became an industrial colony controlled by Americans and devoted to production of sugar cane for the western U.S. market. Sixty years later Hawai`i was a U.S. state. Although this archipelago of six major islands had a long evolutionary history of geological and biological changes due to natural and human forces, it was from about 1850 to 1920 that the ecological changes set in motion by industrial plantation agriculture intensified and permanently transformed Hawai`i's landscape. These seventy years forever changed the forests, water supply, human and animal landscape, marking the first eco-industrial phase of sugar production in Hawai`i. It was predicated upon a steady and massive spread of cane cultivation, constant application of new technologies and scientific principles to the field and the mill, and the evolution of management practices – all essential features of industrialization.

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This article presents a case study of how an industry creates and responds to ecological change. This subject is not well understood – either in the case of sugar or in the case of other industries. Recent articles in *Technology and Culture* and *Business History Review* have reviewed the limited research at the intersection of technology and the environment and business and the environment.¹ They are related to our subject: industrial development and ecological change. In both cases, the authors recognize that studies of technology and studies of business do not usually treat the natural world as an actor impacting upon their subjects. Stine and Tarr suggest that studies of industry and the natural world are needed – especially those examples that present complexity of the relationship. Other than a few promising efforts in the petroleum industry, this area of inquiry is wide open. Rosen and Sellers put forward a terminology – the eco-cultural history of business – hoping to encourage business historians to consider how nature and business are constantly interacting over time, rather than relegating nature to an external consideration (such as pollution). Environmental history in the United States and in Europe offer visions of ecological change in which nature has agency. But focused analysis that combines industrial history and ecological change is nearly absent. Yet, when we look around the modern world, it is industry and the industrialization process that create the accelerated pace of environmental change around the globe. This is, of course, acknowledged by scholars. What we need to know more about, however, is what different industries do to different ecologies. Nor do we understand which aspects of industrialization are important and which are trivial in their interface with nature. To do this requires a combined study of industry history, technological and scientific change, and the evolution of human settlement patterns and institutions within specific ecological settings. This article is offered toward that end.

Industry-Nature Exchange

The industry here is sugar, specifically plantation production of cane sugar. The ecological context is the tropical oceanic island, an environment fragile and remote. The industrial context is the mid-nineteenth to early-twentieth-century world boom in agricultural, technological, and scientific advances. The story of America's industrialization and colonization of Hawaiian Polynesia between 1850 and 1920 is a template for understanding the evolution of the

¹ Jeffrey K. Stine, Joel A. Tarr, "At the Intersection of Histories: Technology and the Environment," *Technology and Culture* 39 (1998), pp. 601-640; Christine Meisner Rosen, Christopher C. Sellers, "The Nature of the Firm: Towards an Ecocultural History of Business," *Business History Review* 73 (1999), pp. 577-600.

industry-nature exchange in the capitalist world of the last century. Oceanic islands have proven to be a laboratory for the study of species evolution because of their geographical uniqueness. For much the same reason, these islands reveal much about questions of interest in the history of the industry-nature exchange of the capitalist west.

In the case of Hawai`i, four aspects of the industry-nature exchange during sugar plantation development reveal several important points: 1) the biogeography of Hawai`i's remote oceanic islands dictated the rapidity of ecological change which was accelerated from time-lines typical on continents; 2) industrialization of sugar production through time created important drivers of ecological change in the evolving social organization of capital and use of advancing science and technology; 3) the environmental needs of industry, especially availability of large quantities of water, set the limits and conditions of industrial survival; and 4) the radical changes in Hawai`i's ecological communities below the upper montane and sub-alpine elevations is the eco-industrial heritage of the two way relationship between sugar production and nature. Each of these is discussed briefly.

Unlike continents, oceanic islands have a unique natural history that makes them vulnerable to populations of imported disease organisms, animals, plants, and humans because of their endemic species, which have evolved over thousands of years without exposure to predators. Flightless birds, plants unaccustomed to fire or browsing mammals, sightless insects – these were typical life forms on remote islands such as in Hawai`i. Population collapse and extinction are regular consequences when these niche species confront continental species.² Oceanic islands have always drawn scientists – from Darwin and Wallace to Robert MacArthur and E.O. Wilson – to study the global trends of extinction, climate change, cultural change, and other ecological processes up close because they occur more rapidly than on the continents. Oceanic islands, such as the Hawaiian archipelago (the most remote island chain in the world) typically have industrial agriculture as the major economic feature, thus offering a valuable case study of the nature-industry interface. As in the study of evolution and biogeography, the ecological aspects of industrialization provide a clearer picture of the results from disturbed ecological processes. The biogeographical context of Hawai`i is based upon arrival and adaptation of species throughout geological time. Similarly, the industrialized environment in Hawai`i is based upon the arrival of plantation agriculture and culturally diverse human inhabitants that adapted and ultimately changed island ecology. Just as the island environment is a microcosm of the evolution of species, it is also a laboratory for the study of the relationship between nature and industry.

² See Waren Wagner, V. A. Funk, *Hawaiian Biogeography: Evolution on a Hot Spot Archipelago* (Washington DC, 1995), on Hawaiian biogeography.

Plantation agriculture has a long history as a colonizing force used by Europe to subdue and exploit tropical ecologies and peoples.³ Cane sugar production is probably the first industry, due to the biochemical properties of the plant which require rapid transportation of cut cane to the mill. The industrialization of sugar production, then, is significant because it created factories in the field in the Americas as early as the sixteenth century.⁴ We associate industrialization with urbanization. Industrial agriculture does not create cities, but it does create new ecologies. And these ecologies, specifically on islands, can alter entire ecological regions and their human communities. Industrial ecological change in island environments, unlike continental settings, very quickly initiates a transformation of society and ecology that can be permanent and unsustainable. It is also important to remember that the relationship between industry and ecology is reciprocal. Industries do have ecological impacts, to be sure, which may be severe and irreversible. But, especially with agriculture, ecology is as important a factor in industrial change as is any other (such as labor, technology, or capital). Nature is a powerful actor in the story of industrialization.

The history of Hawai'i's sugar industry might best be understood as a history of an exchange relationship between nature and industry, between human institutions and bio-physical processes. The rise of plantation production and development of supporting ranching and rice industries, along with importation of new human populations and new settlement patterns, had a decided impact upon the landscape. Not only were cane lands affected, but also distant water sources, wet and dry forests, and fertile wet valleys once settled by ancient Polynesians. By 1920, the plantation's reach included almost all ecosystems of the archipelago. These changes in the delicately balanced environmental system in turn had dramatic effects upon the production of sugar. The first logging of forests above the early plantations on Maui and Kaua'i for fuel in the 1850s and 60s had observed consequences of declining rainfall. One of the world's thirstiest crops, sugar's survival required overcoming this obstacle – which it eventually did. This nature-industry exchange beginning in the 1850s evolved through the decades until neither the industry nor the environment in Hawai'i resembled its original self.

The transformation of multiple ecological regions caused by sugar cane plantation development is Hawai'i's eco-industrial heritage. The idea of heritage, from the field of historic preservation, is a useful concept for the study of the industry-nature exchange. The eco-industrial heritage in a given region is the sum or result of the physical consequences of industrial activity on the

³ See Eric Wolf, *Europe and the People without History* (Berkeley, 1985), on plantations as colonizers and invading forces.

⁴ See Sidney Mintz, *Sweetness and Power: The Place of Sugar in Modern History* (New York, 1985), on why sugar production is the first "industry".

ecological arrangements of a landscape. It includes changes in the built environment, an altered bio-physical environment, and production of an accumulating waste. The eco-industrial heritage of the Hawai`i is the result of the relationship between plantations and their ecologies – creating an environmental heritage in Hawai`i that is unique in the world’s sugar producing regions. There may be similarity in the needs of sugar throughout the world – rich soil, volumes of water, extensive clearing of tropical forests – all which have major environmental repercussions. However, human institutions – economic, political and cultural – play a major role in the ecological-industrial exchange. The way an industry develops, at what cost to human and other populations and to the bio-chemical character of the environment, unfolds according to the interaction between specific human communities and the environment.

Industrialization of plantation agriculture is not necessarily a linear process, nor is it a foregone conclusion – especially in island environments. Many sugar producing regions of the world did not make it to the nineteenth century, let alone the twentieth. Plantation agriculture is dependent upon the demographics of labor supply. In addition, there are complex aspects of plantation development – availability of land, favorable political institutions, business and marketing arrangement – that create unique histories. And finally, the colonizing process of the plantation on the landscape has ecological consequences. The mark of sugar upon the Hawaiian landscape led to an industrialized environment. The interaction between nature, human institutions (plantation), and western land use traditions is at the center of this story.

Ecological Change before Sugar

Hawai`i’s industrialized environment is the product of ecological changes that occurred *before* introduction of sugar production as well as after. The product of volcanic action as the Pacific Plate moved over a “hot spot” of magma, the island environment has evolved over 5.6 million years (when Kaua`i was first formed) as flora and avian fauna arrived from the Indo-Pacific, Americas, and South Pacific, evolving in isolation. As a result, Hawai`i has the world’s highest percentage of endemic species in the world.⁵ Notable in island evolution is the absence of whole classes of species, such as ungulates – a significant factor in future ecological change.

The first humans, Polynesians arriving by canoe as early as A.D. 300 from several thousands of miles to the south to explore and settle in small communities by A.D. 600, brought several new plant and animal species. They intro-

⁵ Linda W. Cuddihy, Charles P. Stone, *Alteration of Native Hawaiian Vegetation: Effects of Humans, Their Activities and Introductions* (Honolulu, 1990), p. 1.

duced their cultivated species of taro, sweet potato, and breadfruit, as well as fire as they burned and cleared the lowland forests on the windward (and therefore wetter) sides of the islands. By about A.D. 800, Polynesians began to inhabit new regions, spreading throughout all of the islands and, clearing the drier (leeward) sides of the islands, developed a form of dryland agriculture. Two agricultural forms emerged: wetland taro cultivation (using irrigation) and dryland cultivation of taro, sweet potato, and other crops. The noted archeologist Patrick Kirch claims that Hawaiian agriculture was the “greatest force leading to environmental change in pre-contact times.”⁶

Hawai‘i became the most highly stratified of the Polynesian chiefdoms, and by the time voyaging trips to the south had ended (about A.D. 1300) large population centers in taro producing regions developed, based on elaborate irrigation systems. During the later period of Hawaiian settlement (A.D. 1650-1795), prior to European contact, the land tenure system of the ahupua‘a emerged which established territorial units that ran from mountain to the sea. The ahupua‘a contained all the major resource zones of the island region and were managed by lesser chiefs under the paramount chief who may have controlled a large region or perhaps an entire island.⁷ Ecological change, particularly during this last phase of population expansion and intensified agriculture, was primarily alteration of vegetation of lowland forests in taro producing valleys and surrounding locales. Fire, too, altered the ecosystem by eliminating habitat for such endemic species as tree snails and lowland birds.⁸

With the appearance of James Cook, British explorer of the Pacific, at Kealahou Bay in 1778, Hawai‘i embarked upon a second wave of ecological change, characterized by a precipitous and rapid decline in Hawaiian population and destruction of forests and grasslands beyond populated districts.⁹ Introduced diseases, along with the release of cattle, sheep, and goats to roam free from protection throughout the islands (especially on Hawai‘i and Maui), took a considerable toll on the sustainability of Hawaiian agricultural centers.¹⁰

⁶ Ibid., p. 18.

⁷ See Patrick V. Kirch, *On the Road of the Winds: An Archaeological History of the Pacific Islands before European Contact* (Berkeley, 2002), for the most recent information on dating of Polynesian settlements in Hawai‘i and the Eastern Pacific.

⁸ Cuddihy, Stone, *Alteration*, p. 25-29.

⁹ J.R. McNeill, “Of Rats and Men: A synoptic Environmental History of the Island Pacific,” *Journal of World History* 5 (1994), pp. 299-349, postulates two major stages in Pacific Island environmental history based upon the Polynesian expansion and the arrival of European Captain Cook. He inserts the development of plantation agriculture in the Pacific as a second phase of the Cook stage. I believe that the industrialization of plantation agriculture created a significant departure (based upon technological change and colonization) in ecological history of Hawai‘i.

¹⁰ Kamehameha, the Hawaiian king, pronounced a *kapu* (prohibition) on killing of the animals given him by Europeans during their early visits. This protection allowed a rapid spread of cattle and goats, in particular, throughout the dry forests of the island of Hawai‘i, exposing

Estimated population at the time of Cook's arrival varies – ranging from 279,000 by demographer Eleanor Nordyke, to 800,000 by historian David Stannard.¹¹ By 1850, Hawaiian numbers had fallen to 70,000; and by 1900 to just under 30,000.¹²

The population collapse evident by 1850 left crippled agricultural districts and deserted villages. Hawaiians migrated to the port towns of Lahaina, Hilo, and Honolulu, signed on to whaling ships, hired on to plantations as contract laborers, and found supplemental income from pulu-gathering expeditions, and small commercial agricultural ventures.¹³ The decline of Hawaiian production created the ecological and political conditions for sugar's colonization of the landscape. In order to sustain Hawaiian independence in the face of a declining native population and growing agricultural chaos in the rural districts, kings looked to resident missionaries for consul. Missionary schools educated the children of chiefs and kings, promoting ideas of individual rights, familiarizing students with nineteenth century commerce, and teaching western agricultural trades. In an effort to preserve Hawaiian culture, yet become a "nation" in the nineteenth century world of commerce, the first monarchs gradually adopted western concepts of political authority and property. Hawaiian scholars today argue that the impetus for this transition was the attraction of Christianity's promise of "everlasting life" to a Hawaiian leadership in the throes of social chaos caused by the collapse of Hawaiian population.¹⁴

The consequences of this second wave of ecological change began with the collapse of Hawaiian agriculture and the spread of species of European ungulates throughout a vulnerable Hawaiian landscape. The secondary effects that followed from these developments furthered environmental change. One example is the sandalwood trade with China that began in the early 1800s which depleted the sandalwood forests during intensive harvesting between 1815 and 1826. Another is the whaling trade in the Pacific that pulled Hawaiians away from their agricultural pursuits to collect firewood and grow potatoes and vegetables to provision ships. Unlike the sandalwood trade, whaling in the Pacific lasted nearly forty years and utilized large quantities of wood to fuel boilers that rendered whale blubber into oil. Wood was also needed to support the

native grasses and plants that evolved without the presence of browsing animals, to extinction.

¹¹ Eleanor C. Nordyke, *The Peopling of Hawai'i. Second Edition* (Honolulu, 1989); David E. Stannard, *Before the Horror: the Population of Hawai'i on the Event of Western Contact* (Honolulu, 1989).

¹² Robert C. Schmitt, *Historical Statistics of Hawaii* (Honolulu, 1977), p. 25.

¹³ Pulu is the soft hair found at the base of Hawaiian tree ferns. It was an export crop primarily from the rainforests of the island of Hawai'i between 1830 and 1880, and was used for mattresses and bedding in North America and Australia.

¹⁴ See Lilikala Kame'eleihiwa, *Native Land and Foreign Desires* (Honolulu, 1992), for elaboration of this argument.

growing port towns that supplied the whalers. Biologists Cuddihy and Stone surmise from the evidence of ecological change during this time that the lowland forests (especially dry forests) were seriously degraded and (in the case of areas impacted by cattle) eliminated and turned into plains.¹⁵

Industrial Sugar Ecology

It is the *third* wave of ecological change in Hawai'i (1850-1920) that has had the most profound effect upon Hawaiian ecosystems. Some argue that the most dramatic ecological changes were wrought by Polynesian and Euro-American introduction of alien species.¹⁶ But plantation agriculture created an entire *industrialized environment* that remade Hawai'i through institutional changes in political authority, economic power, and land use policies. Its demands for land, water, and labor sparked changes in technologies, business organization, and government law and policy that had far-reaching effects. The expansion acreage for sugar and subsidiary industries of ranching and rice-growing would have not been possible without the efforts of sugar planters to redesign land and water policy in their interests. The institutional foundations behind today's environmental heritage were built during this period. By 1920, Hawai'i's land, forests, and water systems were organized according to the clock of sugar manufacture.

Nature sets the rhythm of sugar production to which industry must bow. Sugar juice deteriorates the moment the cane is cut and exposed to oxygen. The rapidity with which the cane arrives at the mill and is ground is the most critical aspect of production – it is what unites the field and the mill under a single regime. This simple fact has led anthropologist Sidney Mintz to claim that sugar was the very first true *industry*, which required synchronization of the mill and the field, imposing the first factory system on workers, managers, and nature.¹⁷

Nature also determines success or failure as well in the separate spheres of the field and the mill. The sugar plant itself, a member of the grass family (*Saccharum officinarum* – Hawaiians call it Ko) is not native to Hawai'i, but was brought to the islands as a minor staple in Polynesian diet. As an export crop, however, it requires volumes of water and labor-intensive work in clear-

¹⁵ Cuddihy, Stone, *Alteration*, p. 38.

¹⁶ The most recent assessment (Richard A. Carpenter, *Environmental Risks to Hawaii's Public Health and Ecosystems*. A Report of the Hawaii Environmental Risk Ranking Study to the Department of Health, State of Hawaii. 2 vols. [Honolulu, 1992]) of environmental risks to Hawai'i's ecosystems identifies the introduction of alien species (past and present) as the highest risk to the islands.

¹⁷ Mintz, *Sweetness*.

ing, cultivating, planting, weeding, and harvesting. Early missionary families and merchants realized that the rich volcanic soils, particularly on the wetter windward sides of islands, were suitable for large scale plantations, and became some of the first plantation owners on Maui and Kaua'i in the 1840s and 50s. Operations in the mill, where sugar cane is crushed, juice extracted, and boiled until it becomes crystallized as raw sugar, must work in delicate tandem with the chemical changes that occur with the boiling of sugar juice. Under the discipline of nature, a developing sugar district in the competitive nineteenth century world sugar market required abundant capital, up-to-date technology, a business strategy supporting sugar production during the unproductive start-up years, a favorable land use and labor recruitment policy by the local government, and the necessary political power to secure a market in a distant nation. This is what it took for Hawaiian sugar planters to move from a tentative, under-capitalized sugar district in the 1850s to the most productive sugar region in the world by the mid-twentieth century.

After a period of trial and error, when Hawai'i entered the world's sugar stage in the 1860s, luck would have it that the American Civil War rendered Louisiana's sugar district unproductive. The California boom after the 1849 gold rush also created a permanently expanding market for Hawaiian sugars. Several well-capitalized Hawaiian plantations that started in the late 1850s – such as Kohala Sugar Company (on Hawai'i island¹⁸), Haiku Sugar Company (on Maui), and Lihue Sugar Company (on Kaua'i)¹⁹ became permanent island fixtures, benefiting from these market developments in the U.S.²⁰ Historian Galloway has called this era part of the “long nineteenth century” of the world's developing sugar industry – a time when the technological revolutions in sugar mills either propelled sugar-producing regions into the next century or brought their extinction.²¹

The true mettle of sugar production then and now is a simple calculation: how much cane (from the field) and raw sugar (from the mill) are produced per acre of cultivation. According to this standard, during the twentieth century,

¹⁸ The largest island in the Hawaiian chain is named Hawai'i, and will be referred to here as Hawai'i island or the island of Hawai'i.

¹⁹ Lihue Sugar Company actually started in 1850.

²⁰ It took 3-4 years once a plantation was established to get sugar to market for a return. And it often took up to 9-10 years before investors realized a profit. See Carol MacLennan, “Foundations of Sugar's Power: Early Maui Plantations, 1840-1860,” *Hawaiian Journal of History* 29 (1995), pp. 33-56, and Carol MacLennan, “Hawai'i Turns to Sugar: The Rise of Plantation Centers, 1860-1880,” *Hawaiian Journal of History* 31 (1997), pp. 97-126, for a review of the earliest years of sugar plantation development in Hawai'i.

²¹ J. H. Galloway, *The Sugar Cane Industry: A historical geography from its origins to 1914* (Cambridge, 1989), details the improvements in the mills which were crucial to the ability of sugar growing regions to survive the “long nineteenth century” of technological improvement and competition.

Hawai'i became the most efficient sugar producer in the world. On the occasion of Hawai'i's admission to the U.S. in 1959, the *Hawaiian Annual* boasted that "Hawai'i's sugar industry achieves the highest yield per-acre production in the world. Annual crops in recent years have averaged up to almost 93 tons of cane per acre. The yield of raw sugar per acre averages up to more than 10 tons."²² Using this standard measure, the table below illustrates two significant trends in Hawaiian sugar industry growth. First, beginning in the 1860s and for another sixty years, acreage of cane cultivation soared from about 10,000 acres in 1867 to 236,000 acres in 1920.

Sugar Crop Acreage, Yield, and Production, 1867 - 1960²³

Year	Acreage	Yield/acre (tons of cane)	Sugar Produced/ tons raw sugar
1867	10,006 ²⁴	N/A	8,564 ²⁶
1879	22,355 ²⁵	N/A	24,510
1891			146,174
1900			289,544
1905 ²⁷	95,443		427,366
1910	110,247 ²⁸		518,127
1920	236,500 ²⁹	41.0	556,871
1930	251,533	61.9	924,463
1940	235,110	62.7	976,667
1950	220,383	74.7	960,961
1960 ³⁰	224,617	83.1 ³¹	935,744

²² *Thrum's Hawaiian Annual* Vol. 84 (1960), p. 269.

²³ *Thrum, Hawaiian Annual*. Data for each year listed is taken from the annual published that year, unless otherwise noted.

²⁴ Sources for 1867 are from *Pacific Commercial Advertiser*, 19 January 1867. For 1879, see MacLennan, "Hawai'i Turns to Sugar".

²⁵ Source is J.S. Walker, Memo: Statement Sugar Plantations of the Hawaiian Islands, 27 August 1879, Interior Dept-loose files, Archives of Hawai'i. See MacLennan, "Hawai'i Turns to Sugar", for a discussion of problems how acreage calculations are derived for both 1867 and 1879.

²⁶ HSPA, 1926, p. 94. For both 1867 and 1879.

²⁷ *Planters Monthly* Vol. 24 (1905), p. 482. Records begin to indicate average yields for the industry, but in figures that are not compatible with later years (yield/lb. of sugar produced – not cane).

²⁸ *Planters Record* Vol. 4 (1911), p. 9.

²⁹ Regular statistics on acreage in sugar cultivation and yield dating back to 1929 are added to the sugar statistics in *Thrum's Hawaiian Annual* which begin with the 1940-41 issue.

³⁰ Production is down in 1959 and 1960 because of a four-month strike in 1958 which had lingering effects upon the sugar crop.

³¹ Note this doesn't quite match the "boast" of nearly 93 tons per acre in the 1960 issue of the *Hawaiian Annual*.

This trend reflects the ability of the industry to expand its productive capacity through land acquisition and water delivery. The second trend appears after 1920 when cane acreage stabilizes around 225,000 and the yield of cane per acre expands from 41 to 83 tons per acre. This reflects the ability of the industry to increase productivity through soil amendment, mechanized harvesting, pesticide application, and conservation of water in irrigated fields.³² The key to success was “improvement” in the field, the mill, and the transportation system between the field and the mill. The process by which the industry “improved” these operations is the engine that drove the industrialization of Hawai`i’s environment. Although today sugar plantations have nearly disappeared from the Hawaiian islands, the political ecology of sugar production between 1850 and 1920 has stamped an indelible mark upon the Hawaiian landscape.

The remainder of this article focuses upon the institutional and ecological foundation of sugar’s rise to power in Hawai`i and its eco-industrial heritage. The permanent changes wrought in Hawai`i’s ecology during the critical time of 1850-1920 are the result of three developments: 1) the business and technological organization of production; 2) the capture and direction of government land use policy by sugar interests; and 3) the response of sugar capitalists and government at the turn of the century to Hawai`i’s ecological losses. Each of these will be examined for the crucial first decades of plantation industrialization. Alone, any one of these developments would not have been sufficient to create the massive, permanent change in Hawai`i’s ecology. In concert these factors led to the erasure of much of Hawai`i’s remaining native environment.

Technology and the Business of Production

Hawai`i’s early sugar capitalists evolved a plantation management and improvement system unique in the sugar-producing world. This was important to the industry’s ability to expand, acquire land, and secure the necessary cooperation from the Hawaiian monarchy. Two strategies proved crucial: the development of an “agency” system for capitalizing plantations and marketing sugar; and the sharing of technological and scientific information, leading to the organization of a planter society. These strategies enabled Hawaiian planters to position themselves in the vanguard of technological development in sugar

³² The period between 1920 and the 1970s, when sugar plantations began to close, was a time of growth benefiting from the environmental framework of business organization, land use policy, and environmental response of the earlier era. It is not the subject of this paper, although would prove an interesting topic for examination because it presents the important problems of pollution from pesticides and soil erosion that resulted from later cultivation strategies and mechanized harvesting.

milling through the pooling of capital and information on cultivation, milling, and the overall science of sugar production.

In the earliest years of development, sugar plantations of the 1850s and 60s were primarily partnerships, the managers often one of the partners. Typically, retired ships' captains and retired missionaries and their sons were the first planters.³³ Although personal funds were utilized to purchase or lease land and construct simple mills, it became apparent that constant infusions of capital were necessary to maintain operations for at least three years until sugars could be marketed in San Francisco. Since plantation labor was generally hired under contract for 3-5 years, bullock and mules to transport wagonloads of cane to the mill needed to be fed, and constant repairs and improvements to milling operations were the norm, there were considerable cash outflows each year. Letters from managers to their agents are full of examples of unplanned expenses and exasperation over realization that returns on production were in the distant future.³⁴ Advances from merchants in Honolulu were a standard means for paying the bills.

Honolulu merchant houses such as C. Brewer & Co, Castle & Cooke, and H. Hackfeld & Co. made their initial profits from the whaling trade. Partners in these establishments were some of the early investors in plantations and, as agents, assumed the responsibility for transportation and marketing of sugars and molasses in San Francisco and other western ports. They also advanced cash, often on an ad-hoc basis during the first years of a plantation, when needed. These advances turned into debts of plantation partners to the agents. Soon, the Honolulu agents had considerable say in investment in improvements, hiring of skilled laborers, or purchase of additional land. In some cases (such as Lihue Sugar Co. on Kaua'i, Haiku Sugar Co. on Maui, and Kohala Sugar Company on Hawai'i island) corporations were formed and partners held shares. The agents for these corporations were more involved in daily decisions from the start.

The market for Hawaiian sugars was volatile between 1850 and 1900. Civil War in the United States encouraged plantation start-ups with high prices, but in 1866, with the end of the war, the bankruptcy of one agent who held several plantations started a decline in investment. Prices rose again with the Reciprocity Treaty between the Hawaiian Kingdom and the U.S., allowing Hawaiian sugars into U. S. ports duty-free, only to fall again in the mid-1880s and the depression of 1893. Price volatility increased planter dependence upon their

³³ On Maui, L.L. Torbert (a ship captain), E. Bailey (missionary at the Wailuku station) and his son, and Samuel Alexander and Henry Baldwin, sons of missionaries in Lahaina, started the earliest plantations.

³⁴ Some of the most detailed letters of the early period of plantation start-ups are in Kohala Sugar Co. and Haiku Sugar Co. manager letters to their agent, Castle and Cooke, located in the Hawaiian Mission Childrens' Society archives.

agents for cash, leading to their eventual control over daily operations of field and mill. Agents, such as Castle and Cooke, became so involved in local plantation activities that they had to approve hiring of all skilled workers, require detailed accounts of mill operations and problems, and eventually asked for statistics on all aspects of production (even preparing a form for all their plantations).³⁵

By 1900, at the time of annexation to the U.S., the power of the Hawaiian sugar industry was firmly held by the nine agents or factors, of which six were major actors in the industry.³⁶ After World War I, these agencies consolidated their holdings into five corporations that virtually owned all sugar (and pineapple) production as well as related banking, utility, ranching, and shipping companies. They were called the “Big Five”: Castle and Cooke, C. Brewer & Co., American Factors, T. H. Davies, and Alexander and Baldwin, Inc. The “Big Five” have been known in Hawai`i and to business observers on the mainland as vertically integrated, concentrated in their ownership of all major island enterprises through interlocking directorates, since about 1930.³⁷ By then all plantations were under their control, as were railroads, shipping lines between islands and to the mainland, utilities, banks, most ranches, and many agricultural support industries. A widely known aspect of this control was its missionary connection. Except for the British firm of T. H. Davies, the factors were largely held by descendants of a very few missionary families: the Cookes, Castles, Alexanders, Baldwins – all of whom had intermarried in the second and third generations (in the late 1800s). Other missionary families held significant stock in individual plantations and minority stock in some of the agencies, such as the Wilcox and Rice families of Kaua`i.

The second feature of business organization that propelled Hawaiian plantations forward in the world sugar industry was the ability of planters and their agents to organize cooperative marketing, labor recruitment, and most importantly for the long term future of the industry, experimentation with new technologies and application of science to the mill and the fields. Planter cooperation began in the 1850s under King Kamehameha’s Royal Hawaiian Agricultural Society in which planters of all types of agricultural crops for export shared experiences at annual meetings. By 1856, however, the annual meetings had ceased. After this, planters would co-operate infrequently on

³⁵ Castle and Cooke Collection, index of correspondence, Bishop Museum Business Archives. This is the first evidence of statistics gathering on plantation operations. For more details on the rise of agencies before 1880, see MacLennan, “Hawai`i Turns to Sugar”.

³⁶ *Hawaiian Annual* 1900. The six major agents were: Irwin & Co., Hackfeld & Co., TH Davies & Co, Castle and Cooke, C. Brewer & Company, and Alexander & Baldwin. Within 20 years Irwin & Co. plantations were transferred to C. Brewer, and Hackfeld & Co. interests were confiscated from their German owners and transferred to families owning the other four agencies.

³⁷ See Gaven Daws, *Shoal of Time: A history of the Hawaiian Islands* (Honolulu, 1967).

individual islands or in marketing agreements with a San Francisco refiner. But these initiatives were only sporadic and short-lived responses to specific problems. It wasn't until 1882 that the Planters' Labor Supply Company organized to co-ordinate labor recruitment of workers outside of Hawai'i and share technological and scientific advice. This organization became the Hawaiian Sugar Planters Association (HSPA) and still exists today.

The Planters' Labor Supply annual meetings were widely attended, their proceedings published, and committees covering all aspects of plantation work, machinery, and issues met frequently during the year and published reports. Active committees in 1882 were organized around such topics as fertilizer and seed cane, transportation, cane cultivation, manufacture of sugar, livestock, forestry, labor and machinery. The organization distributed monthly reports to all members providing information on experiments at individual plantations, reports on Australia (Queensland) and Louisiana sugar growing, and items of interest on mill technology and cultivation. After 1900, the HSPA built an experiment station and hired a chemist and entomologist, who conducted and published research on issues of importance to plantations. New committees (in addition to the previous ones) reflected the direction of interest among planters with a focus upon disease, irrigation, labor-saving devices, and utility of by-products.³⁸

By 1915, Hawai'i was the third largest producer of sugar in the world, behind Cuba and Java. The ability of these three regions to survive the "long nineteenth century" of rapid technological change in the industry is a testament to different factors. For Hawai'i, it is due to the application of science to the field and mill, growing out of the cooperative relations first established in the 1850s among planters, in addition to the centralization of plantation wealth in the hands of a few wealthy companies known as the "Big Five." According to the 1915 report of the HSPA, success stemmed from the unique ability of Hawaiian planters to invest in and apply science to production:

The mainstay of sugar production in Cuba is the abundance of cheap lands.
The mainstay of sugar production in Java is the abundance of cheap labor.
Hawaii has neither cheap lands nor cheap labor. As a substitute for these she has developed and must perforce maintain, an efficiency that is well ahead of that of her foreign competitors.³⁹

The combination of a scientifically active planter organization with the increased centralization of capital and power over production decisions in the agencies rather than the individual plantations was instrumental in Hawai'i's rapid rise in size and productivity on the world stage. It enabled investment in vital new technologies such as vacuum pans, centrifugals, Jamacian trains, and

³⁸ *Hawaiian Planters Monthly* 1904.

³⁹ HSPA, *Annual Report*, 1915, p. 11.

ever larger rollers and crushers in the mills. In the field, while cultivation and harvesting remained dependent upon human labor until well into the twentieth century, the capital investment of agents replaced ox-drawn wagons that moved cane to the mills with narrow gauge railroads and portable tracks. The planters organization aided individual plantations with diseases, insect infestations, innovative fuel supplies (such as cane trash), and experiments with fertilizers, cane varieties, and different cultivation techniques.

Land Use Practices and the Sugar Industry

Ecological change in Hawai'i finds its roots in more than technology and business organization. The social and political changes that resulted in new land practices also had consequential impacts upon the Hawaiian landscape.⁴⁰

After contact with Europeans, Kamehameha I (paramount chief of the Hawai'i island) conquered the other islands by 1820. During that time, until the land revolution of the 1840s, the traditional ahupua`a system of land tenure remained relatively intact. A wedge-shaped piece that ran from mountain to coast, each ahupua`a contained all of the resources necessary to support communities – from wood, ferns, and birds in the higher, wet forests, to dry fields for dryland crops such as sweet potatoes, to valleys supporting irrigation for crops like taro (the dietary staple of Hawaiians), and coastal waters providing protein from fish. Hawaiians had use rights with the ahupua`a to gather, farm, and fish. From time to time, a chief would impose a *kapu*, or ban, on use of a plant or fish to prevent overharvesting. Work in the taro fields was coordinated by chiefs; families also had their own separate plots of land to work. European trading pressures on the Hawaiian chiefs and King, however, took their toll on the ability of Hawaiians to maintain the ahupua`a system in its full form. Anthropologists Marshall Sahlins and Patrick Kirch document the declining conditions of one valley on Oahu that was disrupted by trading practices of the

⁴⁰ This summary of changing land use policies draws upon the work of three scholars: Ralph S. Kuykendall, *The Hawaiian Kingdom, 1778-1854*. Vol. 1 (Honolulu, 1947), Ralph S. Kuykendall, *The Hawaiian Kingdom, 1854-1874*. Vol. 2 (Honolulu, 1953), and Ralph S. Kuykendall, *The Hawaiian Kingdom, 1874-1893*. Vol. 3 (Honolulu, 1967), still provide the best overall comprehensive political history of the Kingdom, drawing upon extensive archival resources. More recently, Native Hawaiian scholars have added important interpretations: Kame`eleihiwa, *Native Land*, on the Mahele, and Jonathan K. Kamakawiwo`ole Osorio, *Dismembering Lahui: A History of the Hawaiian Nation to 1887* (Honolulu, 2002), on constitutional governments of the Kingdom. Also see anthropologist Sally E. Merry, *Colonizing Hawai'i: The Cultural Power of Law* (Princeton, 2002), on the development of law in Hawai'i.

chiefs who sent laborers into the mountains to collect firewood and sandalwood for sale to foreign ships.⁴¹

Under the influence of Calvinist missionaries, by 1850 the Hawaiian King had released Hawaiians from the traditional land tenure system, replacing it with one based upon private ownership.⁴² In 1840, the first written constitution established a legislature and constitutional monarchy. By 1845, the legislative work to privatize property – known as the Great Mahele (land division) – had begun. By the early 1850s, all Hawaiian land was held in fee simple by individuals or by the government. Under the Mahele, land had been divided among three separate interests: 1) the King’s land, which was divided into Crown Lands (held personally by the king) and government lands (which he gave to the Kingdom for use by the people); 2) Chief’s lands, which amounted to very large estates granted in fee simple to chiefs who had held these lands as retainers of the king; and 3) Kuleanas for the “commoners,” which were very small parcels (3-5 acres) available to ordinary Hawaiians who could prove they resided on and cultivated these lands.

In retrospect, probably the most important aspects of the land revolution was granting rights of ownership to foreigners, beginning with the right of foreigners to hold leases of land (1841), and eventually to hold land in fee simple (1847). Hawaiians resisted this development for over a decade. Many petitions and letters to the legislature attest to Hawaiian awareness of the irreversible implications of foreign ownership of land.⁴³

By the end of 1855, with land distribution completed, the imbalance in ownership was striking: Crown lands were about 1 million acres; government lands about 1.5 million acres; chief’s lands totaled more than 1.5 million acres; and kuleanas less than 30,000 acres.⁴⁴ The goal of the missionaries to see Hawaiians as “yeoman farmers” owning their own productive lands under the kuleana system never materialized. Kuleanas were not always sustainable pieces of land. Private property boundaries often prohibited or limited the gathering of food and wood from forests, made cultivating taro difficult because owners upstream diverted water for plantations, and discouraged attempts to grow native foods at the different elevation levels necessary. The land revolution,

⁴¹ Patrick V. Kirch, Marshall Sahlins, *Anahulu: The anthropology of history in the Kingdom of Hawaii* (Chicago, 1992).

⁴² Missionaries who came to Hawai‘i beginning in 1823 were sent from Boston by the American Board of Commissioners for Foreign Missions (ABCFM). They established missions throughout the islands, set up schools, made Hawaiian a written language and printed Hawaiian books and newspapers in the native language. The mission ceased supporting the mission to Hawai‘i in the 1860s, whereupon many missionaries and their adult children stayed and became members of the merchant and plantation community.

⁴³ The Dept. of Interior records for the late 1840s are filled with letters to the Interior Minister from Hawaiians, protesting the ownership of land by foreigners. Archives of Hawai‘i.

⁴⁴ Kuykendall, *The Hawaiian Kingdom, 1778-1854*, p. 294.

instead, made it difficult for Hawaiians to avoid becoming wage workers on plantations, in the pulu trade, or in the port towns of Honolulu, Lahaina, and Hilo.

During the subsequent forty years, land use decisions and implementation of policies constructed a land tenure system that worked to the advantage of large-scale export agriculture and pushed the native Hawaiians off of the land. Beginning in the early 1860s, the Hawaiian government offered land for sale in the central plain of Maui from Wailuku up onto the slopes of Haleakala on East Maui, creating a land rush in which foreigners bought up fertile land and began clearing fields for cane and constructing sugar mills.⁴⁵ The Hawaiian Legislature passed laws establishing boundary commissions in each district to adjudicate conflicts, funded the building of roads and wharfs to insure timely shipments of sugar to market, and in 1876 commenced a major land survey of all Hawaiian lands to settle land titles.

During this time, land quickly passed into the hands of sugar planters and foreign investors either through sale or lease. Crown, government, and chiefs' lands were frequently leased to plantations for twenty-five to fifty years, without any restrictions on their use. Many Hawaiians held on to their small kuleanas, using the lease arrangement with plantations as a form of income while they lived in towns or other locations. Plantation maps from plantations on the Hamakua coast show many kuleanas planted in cane dotted throughout the large fields as late as the 1890s. As Hawai'i approached territorial status, however, plantation agents became anxious about eventually being able to secure clear title to these lands and began to press their managers to buy as many of the kuleanas as possible, offering good prices.⁴⁶

The extent to which Hawaiians had lost control over their lands was revealed with the 1887 Constitution – known as the Bayonet Constitution, which was forced upon the King by a group of planters and merchants demanding government reform. Under the new Constitution, voters (including Hawaiians) had to meet qualifications of either an income of a hundred dollars per year or taxable property worth three thousand dollars – thus excluding two out of three Hawaiian voters.⁴⁷ By 1893, when a committee of merchants and planters organized the overthrow of the Hawaiian government and deposed the Queen, the land revolution that began with the Mahele was complete. Hawaiians owned little land, while almost all of the usable lands were in the hands of plantations

⁴⁵ See MacLennan, “Hawai'i Turns to Sugar”.

⁴⁶ The author's research on land leasing and purchases in the Hamakua District plantations reveals an intense drive to secure kuleanas that were often in the midst of large cane fields. These same plantations, however, seemed comfortable with continued leases with the government of forest, ranch, and cane lands because of good rents and long leases.

⁴⁷ Daws, *Shoal*, p. 252. Osorio, *Dismembering Lahui*, focuses extensively on the implications of the 1887 constitution for Hawai'i's loss of sovereignty in 1893.

and ranchers, either held privately or through long-term, low-rent leases from the government. Although the U. S. government investigated and discussed the concentration of Hawaiian land ownership in so few companies and the land leasing policy of the Territory, little changed. In a bow to U. S. land policy that promoted homesteading, the territorial government promoted a homestead program in an effort to make small farms viable and encourage land ownership among Hawaiians. However, most homesteads were on land deemed unusable by the plantations and never amounted to substantial acreages.

In 1902, when the U. S. Senate Subcommittee began a study of the public land system in Hawai'i, it found the policy of leases to plantations and ranchers "objectionable." Large acreages were rented for long terms at low rents. Within the previous year, several leases (up to 22,000 acres, in one case) had been granted for up to 20 years for as little as \$.03 an acre.⁴⁸

What the Subcommittee found was the continuation of a government leasing policy that had been in place since the 1850s, with only few modifications. Initially, large tracts of land were leased to plantations and ranches by the Minister of the Interior (government land) or the King (Crown land) upon request without public review. In 1876, in response to complaints of favoritism to large propertied interests, the Hawaiian legislature required that leases be granted at public auction. However, not until 1895 did the Minister of the Interior have to justify the use for which land would be leased. The Land Act of that year specified that leased lands be specified by a "class" of use (agricultural, pasture, pastoral agricultural, forest, waste), and designated as "first" or "second" class. Petitioners to the Senate Sub-Committee complained in 1902 that the classification scheme was largely disregarded in the award of rents. Critical of territorial land use policy, the Committee determined that Hawai'i law violated U.S. law, and recommended "that Congress take immediate action suspending the power upon the part of the local territorial government of Hawaii to execute for the present any further leases of either agricultural or non-agricultural lands in the island of Hawaii."⁴⁹ The planters, however, in their letter to the Subcommittee, argued that limitations on ownership and leasing of large acreages were not practical in Hawai'i where nearly two-thirds of the cane produced required irrigation investments from \$100,000 to \$500,000 acres and capitalization of large mills required very large plantations to make profitable the single most important industry in the islands.⁵⁰ In the end, because island economic dependence upon the sugar industry, few changes were made in territorial land use policy.

⁴⁸ U.S. Congress, Senate Subcommittee on Pacific Islands and Porto Rico, *Public Land System in Hawaii* (Washington DC, 1902), p. 7. Several plantations in Hamakua, Ka'u, and Kohala districts were dependent upon leased government land for survival.

⁴⁹ *Ibid.*, 1902, p. 17.

⁵⁰ *Ibid.*, 1902, p.150-151.

Industry Response to Ecological Loss

Other than land, the most important factor in sugar production was water. Water is essential for high yields of sugar juice from cane. Until the early 1900s most plantations were not irrigated, relying solely on rainfall. Because cane fields were usually located below the forest belt on the windward side of each island, the ability of the forested mountains to capture rainfall was critical. Periods of drought slowed growth and delayed harvest – sometimes by as much as a year. This wrecked havoc upon harvesting and milling schedules, causing significant shortfalls of revenue.

From the earliest years in the sugar industry, extensive forest decline due to cutting or grazing animals caused concern. The story of the demise of Capt. James Makee's plantation at 'Ulupalakua on Maui illustrates how aware planters were in the 1860s of the relationship between forest loss and rainfall. The change in climate that ended sugar cultivation was attributed to deforestation on a neighboring island, Kaho'olawe, which

was covered with a dense forest. As the trade winds brought down their clouds laden with moisture, they would commence to gather over the Island of Kahoolawe in the early morning, and the area of this cloud rack would increase back gradually across the channel over the lands of Ulupalakua and every afternoon almost without exception a fine rain fell on that place. With the leasing of the Island of Kahoolawe for a sheep pasture and without taking any precautions to protect the forests, they gradually encroached upon it, until the forest was killed....and no rain fell at Ulupalakua for three and a half years, with a result that that place was dried up and of course abandoned.⁵¹

The first issue of the *Hawaiian Annual* in 1875 raised the issue throughout the Kingdom with an article titled "Decadence of Hawaiian Forests," that called for enclosure of the forests from roaming cattle to protect the native species of koa and 'ohi'a trees.⁵² Soon, the general decline of Hawaiian forests became a recurrent theme at Planter annual meetings, the first of which was held in 1882:

But who, that has lived here for twenty-five years or even less, has not observed the immense destruction which has taken place in our limited forests? The loss from cutting has been small compared with what has been destroyed by cattle and other animals.... The valleys as hillsides almost wholly denuded of trees, the water-ways dry and rocky.... The water supply of today is impure and capricious as compared with that of twenty and thirty years ago. To say that all of this has no connection with the loss of forests is certainly a bold as-

⁵¹ These observations were recorded by E.D. Tenny in *Hawaiian Forester and Agriculturalist* 1909, p. 131-132.

⁵² *Hawaiian Almanac and Annual* 1875, p. 19.

sertion.... Kona, Kau, Kohala, even rainy Hilo, know droughts and water-failures heretofore unknown.⁵³

By 1884, the government established the Hawaiian Agricultural Society with two nurseries under the direction of A. Jaeger to import, propagate, and acclimate plants for replanting the forests.⁵⁴ Progress, however, was slow. Determining which species could survive at the different elevations of Hawai'i's wet and dry forests was time-consuming and frequently unsuccessful.⁵⁵

Meanwhile, individual planters closely monitored rainfall and developed reforestation plans of their own above their cane lands. Trees such as ironwood and eucalyptus were popular and can still be seen through the elevations above the old cane land, especially on the island of Hawai'i. Managers at Lihue, Kaua'i plantations and along the Hamakua coast on Hawai'i island were the first to begin large-scale plantings in the 1880s, believing this would encourage the necessary rains. The Hamakua coast plantations were hit hard by several years of drought during the 1890s. At the 1894 annual Planter meetings, the alarm was sounded:

During the past twenty years, large areas of forest and bush lands have been cleared for agricultural purposes, and a much larger area even has been practically destroyed by cattle; so much so in the latter case, that in the districts in which lie the larger cattle ranches, probably one-half the former area of forest and bush land in said districts has almost entirely disappeared.⁵⁶

The forestry committee, after citing publications on forestry by George Perkins Marsh and the American Association for the Advancement of Science, called for the establishment of forest reserves and a government forestry department to curtail cutting and damage by cattle in what remained of Hawai'i's forests.

Some planters invested in fencing to limit the movement of cattle into forest regions. But, other than the government nursery and individual plantation initiatives, there was no overall industry or government initiative to address the problem of continued forest decline and alarming decline of average rainfall in specific sugar growing regions. It had to wait.

Right about this time, the first discussions of "habitat destruction" as directly related to species decline and extinction were discussed. Ornithologist H. W. Henshaw published the first extensive account of Hawaiian birds and their

⁵³ *The Planters' Monthly* Vol. 1 (October, 1882), pp. 139-140.

⁵⁴ *Hawaiian Annual* 1884, p. 69.

⁵⁵ It is interesting that Jaeger did not look to native forest trees such as 'ohi'a and koa for replanting strategies.

⁵⁶ *The Planters' Monthly* Vol. 12 (1894), p. 522.

habitats for the general public in 1900.⁵⁷ He linked the destruction of Hawaiian forests with decline in native birds, and laid it at the feet of cattle and ranching:

The deforestation of Hawaii is much accelerated by the work of cattle, which are even increasing in numbers under the constantly increasing demand for beef. They browse upon the tender shrubs, vines, and undergrowth, thus not only destroying the young trees and preventing their natural increase, but robbing the large forest trees of their natural protection. The trunks, accustomed to a heavy covering of mosses, lichens, ferns and vines, by which they are protected from the sun and wind and are ever kept moist, succumb to the new conditions, when the sun and wind have free access to them, and sooner or later die. *Thus ohias, koas and other large forest trees are destroyed by cattle though actually untouched by them* [emphasis mine].⁵⁸

The concept of forests as a part of an ecological web of relationships of species first emerged in Hawai'i during the early 1900s. The Board of Agriculture and Forestry hired an entomologist whose first assignment was the study of insect damage of koa trees by span-worms that stripped the trees bare in forests throughout the islands. Although the primary concern was protection of the watershed for sugar cane fields, the evolving understanding of ecological interdependence among forest species helped promote the urgency of action.

In 1900, Walter Maxwell, Director of the Hawaiian Sugar Planters Association, realized the futility of the piecemeal response to forest loss by both planters and government, remarking in his report to the Association: "local efforts, however, do not meet the demands of the forest question from the standpoint of the interests of the islands as a whole."⁵⁹ He called for "a thorough expert examination of the islands and their requirements in permanent forest area, an inspection of the existing forests, and then adoption of means for improvement and maintenance ... because of its bearing upon the immediate and permanent interest of agriculture."⁶⁰

The response of the territorial government was swift, and a delegate appointed by Gifford Pinchot (the new U.S. Superintendent of Forestry) send a forester to survey Hawai'i's forests. Within ten years the territory organized a Board of Forestry, appointed unpaid district foresters, and hired a Superintendent of Forestry. Starting in 1904, Superintendent Ralph Hosmer began the lengthy process of systematically evaluating Hawai'i's forests and setting priorities for establishing reserves and reforestation. In his 1904 report he evaluated each major forest and assessed its rank in priority for reserve status and plant-

⁵⁷ "Complete List of the Birds of the Hawaiian Possessions, with notes on their habits," *Hawaiian Annual* 1902, pp. 55-106; continued in 1903, pp. 73-115.

⁵⁸ H. W. Henshaw, "Complete List of the Birds of the Hawaiian Possessions, with notes on their habits," *Hawaiian Annual* (Honolulu, 1902), pp. 55-106; continued in 1903, pp. 73-115; p. 58.

⁵⁹ *Hawaiian Annual* 1900, p. 74.

⁶⁰ *Ibid.*

ing of trees by the needs of plantations located at lower elevations and their water demands⁶¹ Because of the need to act quickly, he recommended immediate action by both plantations and government in what amounted to a forest policy based upon two premises:

First: For the continued welfare and development of the agricultural interests of this Territory, on which the prosperity of the country depends, it is essential that an ample water supply be assured.

Second: To accomplish this end through the protection of the watersheds and the conservation of the rainfall, forest reserves are necessary and essential.⁶²

Between 1904 and 1920, Hawai'i's modern forest policy evolved based upon the double strategy of "protection and planting." The basic rationale for forest policy was driven by agricultural interests – protection of the watershed. Several new reserves were established each year beginning in 1904. By 1909 about 545,764 acres of forest had been secured under the reserve system, and 16 reserves created.⁶³ In response to planter complaints over logging in forests, the Board of Agriculture and Forestry defined two classes of forest, each requiring different management – the water-bearing protection forest and the non-water-bearing commercial forest.

In the water bearing forest the most important product is *water*, and consequently the forest ought to be so managed as yield permanently the largest possible dependable supply. With the short water sheds, the steep slopes and the susceptibility of the Hawaiian forest to injury, to secure the best results ... it is essential to ... that the forest be maintained exclusively as a protection forest.⁶⁴

By 1920, over 817,000 acres of government and private land were in 47 forest reserves on all the major islands.⁶⁵ Extensive reforestation efforts by plantations and ranches in 1919 and 1920 (mostly alien species) resulted in over 1 million trees planted.⁶⁶

Hawai'i's territorial forest policies set the stage for one of the largest engineering projects ever attempted by a sugar growing region – the construction of irrigation works on all major islands that transported water for miles to new cane fields. Between 1905 and 1920, land in sugar crops swelled from about 95,400 to 236,500 acres, over a 2 ½ fold increase – largely the result of irrigation.⁶⁷ An HSPA study presented at the 1920 annual meeting noted that nearly

⁶¹ *First Report of the Board of Commissions of Agriculture and Forestry of the Territory of Hawaii, 1903-1904* (Honolulu: Bulletin Publishing Co, 1905).

⁶² *Hawaiian Forester and Agriculturalist* vol. 1 no. 11 (November, 1904), p. 303.

⁶³ *Hawaiian Forester and Agriculturalist* vol. 6 (1909) p. 273, 203.

⁶⁴ *Fourth Report of the Board of Commissioners of Agriculture and Forestry of the Territory of Hawaii, 1907*, p. 19. Emphasis by Board.

⁶⁵ *Board of Commissioners of Agriculture and Forestry Report, 1920*, p. 3.

⁶⁶ *Ibid.*, p. 40.

⁶⁷ See table on Sugar Crop Acreage earlier in article.

half of the irrigated crop of sugar came from three watersheds – the Koʻolau mountains on Oʻahu, and the Kohala Mountains and Hilo reserve on Hawaiʻi.⁶⁸ This indicated a radical shift in sugar production with profound consequences for Hawaiʻi’s ecological heritage. Plantations in the drier districts opened some of the largest operations, such as Oahu Sugar Company and Ewa Sugar Company on the dry plains of west Oʻahu. Kohala, Hamakua, and Hilo districts’ plantations expanded their cane growing fields such that the coast of Hawaiʻi island from the dry side of North Kohala all the way to Hilo was planted in cane, except for the water-bearing Kohala Mountains that provided much of the irrigation water.

Irrigation had been a dream for many planters. Some of the earliest schemes to flume water from higher elevations to lower cane fields came from planters who well understood the relationship between forest and rainfall – especially in the districts of Lihue on Kauai and Makawao and Wailuku on Maui. These were the same planters who had pressed the Hawaiian government in the 1870s and 80s to protect forests from roaming cattle and pigs.

On Kauaʻi, planters built small ditches as early as 1856 to deliver water to cane. The Rice ditch, 10 miles long, however, was rather porous, sealed only by tramped soil.⁶⁹ Missionary observers in the 1860s noted that the forests on the flank of the dormant volcano Haleakala on East Maui were noticeably depleted of wood and vegetation. Plantation failures in that region were attributed to climate change related to loss of forest cover.⁷⁰ In fact, the first large water projects were in East Maui – the 17-mile Hamakua Ditch, completed in 1878, and the Haiku Ditch completed in 1879 by San Francisco capitalist Claus Spreckels at a lower level on the same slope (tapping into a different stream) to irrigate a new plantation on the central plains of Maui.⁷¹ Ditches built during these early years captured water from distant streams in densely forested, unpopulated regions upslope from plantations. Along the ground they were unlined. Across the numerous gulches they were wooden flumes or staves. Leakage was a problem, but sufficient water was delivered nonetheless to make cultivation profitable. Before the irrigation projects of post-1900, these plantations on Maui and Kauaʻi represented a relatively small percentage of production.

The multiple-year drought along the Hamakua coast (Hawaiʻi island) in the 1890s galvanized the numerous small planters in that district to press upon the government to protect the forests. These planters were also dependent upon water from the nearby streams in the Kohala mountains to flume sugar down the slopes to the mills near the coast. Because of the high rainfall creating

⁶⁸ HSPA, *Proceedings of Annual Meetings*, 1920.

⁶⁹ Carol Wilcox, *Sugar Water: Hawaii’s Plantation Ditches* (Honolulu, 1996), p. 54.

⁷⁰ MacLennan, “Foundations”.

⁷¹ *Hawaiian Annual* 1879, pp. 28-29.

muddy roads and washed out gullies, transport of cane to the mill by oxen and later by narrow gauge rail was not as reliable as the wooden flumes that channeled water using gravity to transport the cane. On the other side of the Kohala Mountains, the plantations in North Kohala had each built pumping stations and reservoirs to irrigate some of their acreage, but the drought of the 1890s limited their individual efforts.⁷²

After Hawai'i passed the Forest Act of 1904, the Honolulu agents began a massive investment in irrigation to tap the water wealth from the new forest reserves. In anticipation of a new forest reserve policy, Honolulu capitalists brought one of the world's foremost irrigation engineers, Michael O'Shaughnessy, to the islands in 1899 to plan and engineer several large ditch projects, including the Kohala Ditch and the Upper and Lower Hamakua Ditches in the early 1900s. The discovery of underground sources of water on the Ewa plains of Oahu in the 1890s opened up new sources for irrigation through well-drilling. By 1923, after completion of massive construction and drilling projects that delivered surface and underground waters to plantations, over fifty percent of the sugar cane fields in Hawai'i were dependent upon irrigation.⁷³

One of the most remarkable engineering water projects was the Waiahole Ditch, which transferred water from one side of O'ahu to the other. Tapping into numerous streams and springs on the windward side, sending water through tunnels and ditches in the Ko'olau Mountains, to the dry Ewa plains of the Oahu Sugar Company, the Waiahole Ditch was completed in 1916 at a cost of \$2.3 million. A 2 3/4 mile tunnel in the Ko'olau Mountains was considered an engineering triumph at the time.⁷⁴ On Kaua'i, the early primitive ditches of the 1850s behind Lihue plantations were improved and expanded to sixty miles of tunnels and ditches serving four plantations.⁷⁵ On Maui, the ditches supplying the dry central plain of Maui (Waihe'e commons) came from both West and East Maui mountains to supply Wailuku Sugar Company and Hawaiian Commercial and Sugar Company (HC&S). The Kohala Mountains on Hawai'i supplied three extensive ditches: Upper and Lower Hamakua Ditch bringing 15,000,000 gallons of water daily to three Hamakua coast plantations; and the Kohala Ditch transporting irrigation water 25 miles to four plantations in the Kohala district.⁷⁶

Development of artesian supplies of water for irrigation occurred at the same time. The most extensive project was the drilling of 61 artesian wells on O'ahu's Ewa plain in the early 1900s, supplying Ewa Sugar Company with up

⁷² See Wilcox, *Sugar Water*, on the genesis of Hamakua and Kohala water development.

⁷³ W. P. Alexander, *The Irrigation of Sugar Cane in Hawaii* (Honolulu, 1923), p. 1.

⁷⁴ Wilcox, *Sugar Water*, p. 98. According to Wilcox, there were thirty seven diversions of water from windward streams into the Waiahole Ditch.

⁷⁵ Alexander, *Irrigation*, p. 3.

⁷⁶ *Ibid*, p. 5.

to 80 million gallons of water per day, upon which it was dependent for the irrigation of its fertile, but dry soils.⁷⁷ Some plantations also augmented their water supply from ditches with pumped water. Finally, on some islands, electricity was generated by water power diverted from distant mountain streams to run pumping stations.

In short, by 1920, stream diversion, water transport through flumes, ditches, and tunnels, dam building and reservoir storage, pumping of groundwater sources, and hydro-power were part of a complex water diversion system that changed Hawai`i's sugar industry. An HSPA report reported that by the end of 1914, by which time most irrigation works were completed, twenty-four irrigated plantations had invested over \$12.8 million in reservoirs, pumping plants, pipe and ditches, and flumes for irrigation purposes.⁷⁸ At that time, of 114,000 acres of cane land leased and owned by plantations, 98,962 acres were harvested – of which nearly 60% were irrigated. The yield of cane per acre was remarkably high for irrigated plantations. O`ahu's plantations, of which 98% were irrigated, yielded 50.7 tons per acre. Compare this with Hawai`i's plantations, of which only 7% of the acreage was irrigated, which yielded only 35.1 tons of cane per acre.⁷⁹ Engineering water diversion for sugar production in Hawai`i proved to be one of the most important turning points in the industry's history. In his HSPA report on irrigation in 1923, Alexander makes this apparent: "In order to grow profitable crops, over fifty percent of the sugar cane area in the Hawaiian Islands depends almost entirely on irrigation. The tonnage produced on these irrigated plantations represents over two-thirds of the total sugar crop. Noel Deerr has stated that the privately owned irrigation works in the Hawaiian Islands are unparalleled in other sugar countries."⁸⁰

Hawai`i's Eco-Industrial Heritage

Seventy years of sugar's expansion changed the face of Hawai`i. Besides lands and waters devoted to cane, extensive ranching and rice industries were built by 1920 to supply necessary beef and rice to a growing Asian workforce on the plantations. Ranches occupied the higher elevations above the cane fields from about 1500 to (on Hawai`i island) up to 5-6,000 feet elevation. Pastureland accounted for the largest portion of government leased lands. Above those were

⁷⁷ Ibid, p. 6.

⁷⁸ Ibid, p. 7. By 1923, when this study was completed, another \$5 million had been spent on completion of the Waiahole ditch and a new Maui ditch.

⁷⁹ Ibid, p. 6.

⁸⁰ Ibid, p. 1. Deerr's 1905 *Sugar and Sugar Cane* was the standard volume on world sugar production of the early twentieth century.

the forests. Rice fields occupied the abandoned taro fields of the major valleys on O'ahu and Kaua'i.⁸¹ Sugar's reach onto the Hawaiian landscape extended well beyond the plantations, affecting even remote ecosystems high up volcanic mountainsides.

As sugar expanded during the nineteenth century it was faced with an ecological dilemma threatening its survival. Forest loss created a wave of organization by planters for public protection of remaining rainforests and mobilized Honolulu capitalists to embark upon an irrigation project that promoted Hawai'i to a major sugar producer of the twentieth century. This industry-nature relationship was nurtured during the early years of sugar's development by the unique organization and centralization of capital among a handful of powerful agents, sharing scientific knowledge and technological lessons among the plantations, and the ability of the sugar capitalists to steer the Hawaiian Kingdom toward their ends in decisions about land, water, and forests.

Ecological change in Hawai'i is most easily measured in terms of alteration of natural vegetation. The most extensive land clearing for sugar plantations occurred in the last decades of the nineteenth century and the early twentieth century, permanently removing all native plant cover. Ranches above the plantations converted large tracts of upland forests into pasture and spread alien grasses. Land clearing has recently been identified as the cause of the high rate of extinction of Hawai'i's endemic species. Two-thirds of native bird species, more than 50% of endemic land snails, and 10% of native plants are extinct. 40-50% of remaining endemic plants are threatened.⁸² Most native vegetation and remaining animal species are now located in the high-rainfall regions that are protected by the forest reserve system.

Very little land in Hawai'i is now devoted to sugar, the result of plantation closings in the 1970s and 80s. The land now cleared is for urbanization (especially on O'ahu) and resort development. Introduction of alien species continues. Other than inside the rainforest reserves, Hawai'i's environment is a blending of flora and fauna from all regions of the world. This is the eco-industrial heritage of sugar's first seventy years in Hawai'i.

⁸¹ The rice industry, owned primarily by Chinese, flourished until the 1910s when the demand for short grain rice among the expanding Japanese workforce increased imports of rice from California.

⁸² Cuddihy, Stone, *Alteration*, p. 104.