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ENVIRONMENTAL EXTERNALITIES IN HAWAII AGRICULTURE: POTENTIAL REMEDIES AND TRADE-OFFS

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ABSTRACT

Hawaii agriculture is considerably different from that of the Mainland of the United States in terms of its principal crops, production practices, and ecology. This article outlines the environmental problems faced in that state pertaining to irrigation practices, agricultural chemical use, soil erosion and compaction, and air pollution. It examines potential solutions to these problems. Emphasized in the policy considerations are the constraints posed by the island location, the international agribusiness nature of the largest producers, and the need for such national programs as the soil conservation program to specialize programs to accommodate Hawaii agriculture.

Agriculture is the third largest sector of the Hawaii economy ranking only behind tourism and Federal expenditures. In 1989 the market value of agricultural products sold was $577.5 million. Estimated total farm acreage in Hawaii for 1989 was 1,720,000 acres with 245,300 acres cropped. The three leading crops in Hawaii, namely sugar cane, orchard crops, and pineapples, accounted for slightly over 170,880, 32,000, and 32,700 acres respectively in 1989 [1].

Like mainland agriculture, Hawaii agriculture contributes to environmental problems. For example, groundwater is contaminated in Hawaii by pesticidal residue associated with irrigated agriculture. Other externalities include: air pollution, caused by field burning after harvesting sugar cane, that reduces sight lines

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for views that are valuable to the tourist industry; soil compaction caused by large and heavy machinery used on pineapple and sugar cane fields; and sheet and rill erosion causing a loss of thousands of tons of soil on an annual basis. Pesticides and herbicides contained in irrigation runoff contaminate groundwater, surface fresh water, and even the ocean in case of marine outfall.

The agricultural sector is dominated by large plantations owned by corporations representing absentee ownership. Many of these oligopolistic companies own plantations throughout the world and can move production to other sites should production costs become too high or yields become too low due to environmental regulations, fees, or assessments. This condition complicates any attempt to regulate environmental quality associated with agricultural production. It has been noted that some sugar cane and pineapple production has already been transferred because of noncompetitive cost conditions and increasing land values resulting from urbanization [2]. A major difference from the crops grown on the mainland is that the two leading crops in Hawaii, pineapple and sugar cane, have growing seasons in excess of one year. Sugar cane and pineapple have multi-year production cycles. Ratooning is a common feature for both of these crops. Ratoon propogation is when a crop is allowed to sprout or grow from the root or shoot of a perennial plant. This results in more extensive use of pesticide, herbicide, fertilizer, and irrigation inputs for each crop cycle. This article will look at the kinds of pollution found among the leading crops in Hawaii and the trade-offs involved in various suggested solutions to the pollution problems.

LAND IMPACTS

Soil Erosion

Soil erosion inflicts major economic damage on recreation, water treatment, water storage, irrigation, and soil productivity. Depletion of top soil lowers yield and increases fertilizer use. Silt raises the cost of operation and maintenance of water control projects and harbors. Sediments in agricultural runoff frequently contain fertilizers and pesticides which add to the negative effects on marine recreation, water treatment costs for municipal and industrial users, and aquatic species.

Typically, the Universal Soil Loss Equation (USLE) is used to estimate soil erosion in the United States. In Hawaii, this equation tends to overstate soil loss from erosion because the crop and management factor (the C Factor defined by soil scientists) used in the USLE fails to account for the types of crops, tillage practices, cover conditions, and hydrologic soil groupings unique to the state. When a modified universal soil loss equation (MUSLE) is used for a range of C values reflecting local management and tillage practices, soil loss estimates have been consistently lower [3]. The 1982 National Resources Inventory of the U. S. Department of Agriculture has estimated that 31 percent or 102,000 acres of

Table 1. Estimated Average Annual Soil Erosion in Hawaii (1982)

	Sheet and Rill Erosion	
	1,000 Tons	Tons/Acre
Nonfederal rural land	14,876.6	4.1
Cropland	2,115.0	6.4

Source: United States Department of Agriculture, *The Second RCA Appraisal: Soil, Water, and Related Resources on Nonfederal Land in the United States*, Washington, D.C., June 1989.

Hawaii cropland is eroding in excess of the T-criterion for highly erodible lands. The T-criterion varies by soil type and measures the maximum soil loss tolerance for specific soils. It is expressed in tons per acre and it denotes the maximum annual average soil loss that will permit a high level of production economically and indefinitely [4]. All of this erosion is of the sheet and rill type and none is due to the wind [5]. The National Resources Inventory has also calculated an erodibility index (EI) by multiplying the erosion equation factors representing soil, topographic, and climatic conditions and dividing this product by the soil loss tolerance assigned to the soil [5]. The erodibility index (EI) measures the inherent erodibility of the soil. A rating of 0 to 5 implies standard sheet and rill erosion which can be treated and brought down to acceptable levels through rotation practices. A 5 to 8 rating implies moderate level of erosion and requires greater management. An 8 to 15 rating suggests highly erodible lands that require drastic action. A greater than 15 rating suggests excessive erosion and is difficult to treat [4]. According to this rating scheme, 143,300 acres had a rating of less than 5, 59,300 acres were rated between 5 and 8, 71,000 acres were rated between 8 and 15, and 58,800 acres were rated greater than 15. The soil loss due to sheet and rill erosion is shown in Table 1.

The long growing seasons associated with sugar cane (28 to 45 months) and pineapples (18 to 36 months) imply that there is a large time elapse between plowing, disking, and replanting of the crops. Generally, after four to six months of growth both crops provide canopy cover for the soil which greatly reduces the impact of rainfall on the surface and thus reduces erosion. In the case of pineapple, plastic strips used to control weed growth increase soil temperature, conserve moisture prior to plant establishment and also reduce runoffs that lead to soil erosion. C values for pineapple fields tend to be higher than for sugar cane fields due to differences in tillage, use of plastic on the pineapple fields, and the higher percentage of field area in roads required for pineapples [3].

Suggested methods for controlling soil erosion on Hawaii croplands are conservation tillage, terracing, and growing of a cover crop. One way to reduce soil erosion is to carry sugar cane and pineapple fields through second ratoons. Ratoon field preparations require shallow ripping of 5 inches maximum by a clodbuster. The Schmeiser cultipacker using ultrasonic oscillators shatters the soil and minimizes clods [6]. Nationally, such minimum tillage is shown to have reduced erosion by 50 percent compared to conventional tillage [7]. However, the ratoon harvests have been shown to provide lower yields in comparison to primary harvests although the ratoon harvests contribute to energy savings.

The purpose of a terrace is to slow the speed of runoff, stabilize its flow, and/or to direct the flow of runoff so as to prevent gully development. Terracing designs in Hawaii should allow for the surface roughness of the sugar cane tillage operation, undulating topography, and the erosion resistance quality of its soil groups. However, outlets for the terraces pose major problems that discourage use of these devices in Hawaii. Other problems in terrace use include high installation costs, high maintenance costs, long steep field slopes, undefined drainage, and dry soils [8].

It is possible to plant fast growing leguminous crops as a cover crop in Hawaii. Such crops would not only prevent erosion during the establishment stage of the cane crop but also enrich the soil due to their nitrogen fixation attribute. Plantations, however, seldom follow this practice as they prefer not to grow any crop that competes for moisture and nutrients with the main crop [8].

Soil Compaction

Soil compaction results from mechanized tillage practices and infield transport. It has the effect of reducing yields and increasing the energy budget of crops. Increased energy use stems from the farmers attempt to recover tilth in compacted fields, from increased movement of vehicles in freshly tilled fields and because of compensating increases in fertilizer, pesticide, and herbicide usage rates to maintain productivity of the land [9]. The increased use of agrichemicals in particular increases the environmental hazard due to runoff, leaching, and percolation of the residues.

Studies in no-till farming with subsurface drip irrigation conducted in Kamuela, Hawaii and the Waimanalo Experiment Station on Oahu showed that yields of lettuce were not substantially affected when the soils were protected from mechanized traffic. When a compaction treatment was added to the experiment, head size and quality were uniform but roots in compacted fields were smaller and lighter than in noncompacted fields. Soil compaction also increased orifice plugging of the subsurface irrigation system. There is also recorded evidence that the yield of sugar cane in Hawaii declined by as much as 58 percent (from 88.4 Tons/acre to 37.0 Tons/acre) when the bulk soil density increased from 0.49 grams/cc to 0.56 grams/cc due to soil compaction [9].

Table 2. Agricultural Water Use in the State of Hawaii by Source 1985 (million gallons/day)

Water Use	Groundwater	Surface Water	Total Ground and Surface Water
Agriculture	333	568	901
Total	658	747	1,405

Source: Hawaii Department of Health, *Strategies for Protection of Groundwater Quality in Hawaii* (Revised Edition), p. A4, June 1988.

Correction of subsoil compaction by practicing conservation tillage helps increase yields in especially drought prone, unirrigated fields. In situations where there is abundant water supply, eliminating the soil compaction problem could help reduce pumping costs and improve fertilizer use efficiency [9]. On the other hand, change in tillage practices to rectify soil compaction problems can add to the risk of farming operations due to increased variability in yields, quality, and costs and its consequent impact on profitability of the crop enterprise.

WATER POLLUTION

Agricultural use accounted for 64 percent of all the water used in Hawaii per day in 1985. Broken down into groundwater and surface water, this amounted to 50.6 percent of the groundwater and 76 percent of the surface water used per day. Within agriculture, 37 percent of the water used per day is from groundwater sources and 63 percent from surface water sources [10]. The exact quantities are shown in Table 2.

The quality of surface water and groundwater in Hawaii is generally regarded as excellent [11]. However, agricultural practices tend to affect the quality of both. Agricultural practices affect surface water quality through nonpoint pollution. These stem from runoffs due to rainfall on fields as well as irrigation practices. The runoffs bear soil sediments, dissolved plant nutrients, and agricultural wastes.

Groundwater quality and its geohydrologic environment can be impaired due to overpumpage in irrigation and due to fertilizers and other soluble chemical being leached into basal aquifers. Overpumpage in Hawaii largely results in salt water intrusion in coastal areas rather than subsidence [12]. Recent studies by the groundwater protection program of the Hawaii Department of Health [10] show pesticidal contamination of groundwater. Table 3 identifies the organic compounds which have been found at significant levels (critical PPM) in Hawaii's drinking water/groundwater as of June 1988.

Table 3. Health Risks Associated with Confirmed Reports of Synthetic Organic Compounds in Hawaii's Drinking Water/Ground Water as of June 1988

Common Name (Acronym)	Non-Carcinogenic Effects in Animals Considered in Establishing EPA Health Advisories[a]	Carcinogenic Effects[b]
Ametryn	Liver effects	Not classified
Atrazine	Heart and liver effects	Possible
Carbon tetrachloride	Liver effects	Probable
1,2-Dibromo-3-chloropropane (DBCP)	Reproductive and kidney effects	Probable
1,1-Dichloroethylene	Liver effects	Possible
1,2-Dichloropropane (DCP)	Liver effects	Possible[c]
Dieldrin	Liver effects	Probable
Ethylene Dibromide (EDB)	Reproductive effects	Probable
Hexazinone	Liver effects	Not classified
Lindane	Liver and kidney effects	Possible
Tetrachloroethylene (PCE)	Liver and kidney effects	Probable
Trichloroethylene (TCE)	Liver effects	Probable
1,2,3-Trichloropropane (TCP)	Liver, kidney, heart, and stomach effects	Not classified
Trihalomethanes (THMa)[d]	Liver and kidney effects	Probable

Source: Hawaii Department of Heatlh, *Strategies for Protecting Groundwater Quality in Hawaii* (Revised Edition), Table 4, p. B-23, June 1988.

[a] These are non-carcinogenic effects upon which a No Observed Adverse Effect Level (NOAEL) has been established in an EPA Health Advisory. Other references, as indicated, were used when no EPA Health Advisory was available.
[b] Classifications used by the Carcinogenic Assessment Group, EPA.
[c] EPA Ambient Water Quality Criteria.
[d] Produced naturally when chlorine is used to disinfect water.

Irrigation

Table 4 presents the irrigation characteristics in Hawaii. Irrigation affects environmental quality by reducing fresh water inflow to estuaries which adversely affects fish and wildlife habitats. It also reduces stream flow during low flow periods which limits instream beneficial uses for recreation, aquatic life, and drinking water quality needs. The most practiced method of irrigation is ditch or

Table 4. Irrigation Characteristics in Hawaii

Crops	Water Source	Irrigation Method	Current Withdrawal of Water
Sugarcane	Groundwater[a]–46%	Sprinkler–30%	Agriculture
Pineapple	Reservoir–1%	Surface–41%	Domestic
Orchards, berries	Streams–53%	Drip–29%	
Vegetables			
Forage			
Field crops			
Flowers			
Taro			

Source: Adapted from *Irrigation Water Use and Management*, Interagency Task Force Report, U.S. Department of the Interior, U. S. Department of Agriculture, and U. S. Environmental Protection Agency, Washington, D.C., Table 20, p. 108, 1979.

[a] Pumped wells.

furrow irrigation which is currently being replaced by sprinkler and drip irrigation systems. Drip irrigation doubles water use efficiency and thus reduces the amount of water that must be pumped. Accordingly, the upconing of saline water is reduced. Drip irrigation under flat culture of sugar cane in Maui has produced yields as good as furrow yields but using less water. Based on actual yield of drip irrigated sugarcane, drip irrigation was found to have a water utilization rate of 85 percent. The comparable figures for furrow methods and sprinkler methods were 50 percent and 75 percent respectively [13]. However, while drip irrigation was technologically efficient, it also exhibited higher production costs resulting from high installation and maintenance costs. Thus, it may not be economically efficient. For some crops, the adoption of drip irrigation may represent a tradeoff of technological efficiency in an environmental sense for economic efficiency. Table 5 shows that drip has been adopted for sugar cane, macadamia nuts, pineapples, papayas, guavas, and flower and nursery products.

Recycling

Recycling agricultural water promotes both energy and water conservation [14]. In 1979, over 8.1 percent or 32,270 million gallons of water used in agriculture were recycled water. Recycling water in agriculture results in avoided payments for high priced freshwater, greater use of nutrients contained in the water, freeing superior quality water for higher use and saving surface waters from effluent discharges and consequent water treatment. Treatment costs could affect the cost of producing a crop in a fairly significant manner. For example, farmers in the

Table 5. Distribution System by Crop Activity and Associated Pressure Requirements

System Type	Crops Irrigated	psi
Solid set	Sugar, bananas, lettuce	45
Drip	Sugar, macadamia nuts, pineapples, papayas, guavas, and flowers	25[a]
Boomspray	Pineapples	25
Hand rove	Bananas, lettuce	35
Center pivot	Corn	110
Side roll	Feed and forage (alfa-alfa)	65
Surface	Taro	10
Overhead	Lettuce	45

Source: P. Kasturi, Optimizing Land, Water, and Energy Use in Hawaii's Agricultural Production–1990 Under Multiple Energy Scenarios: A Linear Programming Approach, Ph.D. Dissertation, Department of Agriculture and Resource Economics, University of Hawaii, Honolulu, 1983.

[a] Personal communication: Harris M. Gitlin, agricultural engineer, Department of Agricultural Engineering, University of Hawaii, Honolulu, Hawaii.

Kula area in Maui whose source of irrigation water is the same as for domestic use are required by the Clean Water Act and the Safe Drinking Water Act to internalize the cost of cleaning water supplies. National Pollution Discharge Elimination Systems (NPDES) permits in Hawaii which govern discharges into waterways or into open waters restrict all island plantations to zero point discharges with the exception of the Hamakua coastline on the island of Hawaii. It was estimated that by 1982, plantations in that area were spending $3 million annually to meet the NPDES permit requirements [14]. Cleaning up wash water has shown that soil could be accreted at the rate of 1600 dry weight tons per day. Thus besides preserving good soil, recycling water in agriculture has the beneficial impact of regulating the flow of sediments containing pesticide residues and other contaminants into the open waters of the ocean. This prevents discoloration in coastal areas which could be a visual blight for the tourism industry. It also prevents damage to aquatic life and enhances the quality of marine recreation. While the farmers face increased treatment costs, some of these costs will be offset by reduced pumping costs for irrigation due to the replacement of groundwater by the recycled water.

Fertilizers

Agricultural production in Hawaii's plantations is accompanied by a high rate of inorganic fertilizer application. Table 6 provides nitrogen fertilizer application

Table 6. State of Hawaii Estimated Average Nitrogen Fertilizer Application Under Different Alternatives in 1990

Crop	Conventional Tillage	Conservation Tillage
Sugarcane	173.8	130.9
Pineapples	442.3	442.7
Macademia nuts	131.8	131.8
Coffee	68.6	68.6
Papayas	105.8	101.6
Guavas	53.0	53.0
Bananas	85.0	86.9
Flowers and foliage	210.4	210.4
Feed and forage	30.7	30.7
Lettuce	127.6	127.6
Taro	203.8	203.8
Seedcorn	348.6	348.6
Total Hawaii Average	207.8	171.4

Source: P. Kasturi, Optimizing Land, Water, and Energy Use in Hawaii's Agricultural Production–1990 Under Multiple Energy Scenarios: A Linear Programming Approach, Ph.D. Dissertation, Department of Agriculture and Resource Economics, University of Hawaii, Honolulu, 1983.

rates for the major crops in Hawaii both under conventional as well as conservation practice. High rates of fertilizer application could cause pollution of surface and ground waters from runoffs and soil leaching. Excessive growth of algae and aquatic plants result from eutrophication of surface waters by nitrogenous and phosphoric fertilizers. In turn these plants reduce the dissolved oxygen in the waste waters and make it unhealthy for watersports, swimming and aquatic foods.

Knowledge regarding pollution of groundwater by fertilizers is limited. There is little information regarding quantities of pollutants that enter groundwater and the aquifers ability to handle these effluents. It is generally known that nitrogen is mobile and percolates into the aquifer with irrigation water while phosphorous compounds react with the soil. A 1985 U. S. Geological Survey utilizing data from a twenty-five-year-long study failed to reveal nitrate-nitrogen concentrations of 10 mg/liter (EPA toxicity limit) in any of the 164 wells sampled in Hawaii [10]. Toxic concentrations of nitrates in groundwater cause the "blue baby" disease as well as methemoglobinemia in rural areas [15]. It has been shown that heavy annual application of fertilizers that would allow more than 13.5 pounds per acre to pass beyond the root zones could raise nitrate concentrations to the toxic level. In this context it must be noted that the average feet of lift for groundwater for the entire United States is 126 feet as compared to 700 feet for Hawaii [16]. Thus presumably, Hawaii's lands could withstand higher dosages of fertilizer application without fear of contaminating groundwater aquifers. But the potential for nitrate concentration buildup in Hawaii's groundwater could be reduced if lesser nitrogen fertilizer was applied per acre.

There are three ways to reduce inorganic fertilizer usage and thus indirectly reduce nitrate leaching. One way to reduce nitrogen application is to switch to dryland cultivation which would also prevent leaching of nitrates below the root zone from the use of inefficient irrigation methods. However, yields from drylands are typically lower than from irrigated lands in the case of sugarcane. Another way to avoid nitrate leaching is to use "slow release" and "controlled release" fertilizers. Use of these fertilizers results in improved fertilizer use efficiency, minimizes the loss of nutrients in agricultural runoffs, prevents leaching of salts below the root zone due to percolating irrigation waters and substantially limits the salinity potential to crops [17]. Anthurium growers in Hawaii have over two decades of experience in using this type of fertilizer. Other crops that could benefit from the controlled release fertilizers are sugarcane, pineapples, fruit orchards and nursery crops. Controlled release fertilizer can be incorporated into the plastic mulch culture and is compatible with furrow and drip irrigation methods. A third method of reducing nitrate leaching is to use farmyard manure. Hawaii's sizable livestock industry generates substantial amounts of organic wastes. It has been estimated, on the basis of 1979 manure production and fertilizer usage rates, that with effective utilization, farmyard manure has the potential to contribute up to 25 percent of the nitrogen, 19 percent of the phosphorous, and 39 percent of the potassium used in Hawaii agriculture [18]. While this alternative reduces the purchase of commercial fertilizers, some offsetting pecuniary costs are incurred in collecting and spreading manure as well as environmental costs in terms of sight and odor.

Pesticides and Other Chemicals

Pesticide usage per capita in Hawaii is ten times the national average [18]. Table 6 lists the health risks associated with confirmed reports of synthetic organic compounds in Hawaii's groundwater. Herbicides, fungicides, insecticides and other chemicals are used for nematode control, weed control, insect control, disease control, floral induction and fruit maturation in plantation agriculture. Synthetic organic compounds that are used as pesticides enter watercourses due to runoffs or may be leached into the groundwater. Their complex molecular structure is not affected by stream biota and they become persistent pollutants. During the early 1980s, certain pesticides (organochlorines and organobromides) were detected in drinking and ground water, forage material and fruits. In 1982, heptachlor in pineapple green chop used as feed material for dairy cows resulted in contamination of milk supplies in the state [19]. Heptachlor causes cellular poisoning and liver damage. Papayas grown in the state that were fumigated with ethylene dibromide (EDB) were denied access to California markets [20]. Another fumigant DBCP used on pineapple fields contaminated drinking water supplies in a section of Oahu [21, 22]. Both EDB and DBCP cause sterility in males and carcinoma. Watercress was found to be contaminated by endosulfan. In high doses this chemical affects the central nervous system causing convulsions, spontaneous contractions and may induce a comatose condition [23]. Mirex used in sugarcane and pineapple fields till the late seventies to control ants was found to be extremely toxic to shrimp, oysters, shellfish and other marine organisms that had zero tolerance to this chemical even when present in trace amounts in streams, rivers and openwaters.

A 1985 report of the U. S. Environmental Protection Agency on State Ground-Water Program Summaries lists Hawaii's groundwater contamination by agriculture in general and pesticides in particular as being most severe [24]. Pesticide usage can be reduced by using herbigation. Herbicides and insecticides can be injected through the irrigation system using overhead sprinklers [25]. Since agricultural aircraft are also used in Hawaii, using infrared equipment onboard to spot disease centers precisely with aerial mapping is yet another way to moderate otherwise excessive or unnecessary usage of these chemicals [26]. A third method that could benefit Hawaii is Integrated Pest Management (IPM). This system frequently integrates chemical, biological and cultural techniques to improve economic returns and environmental quality. Hawaii has been a leader in the area of biological control for well over a century and has had some notable success stories. Biological control of the sugarcane leafhopper and the banana skipper have rescued these industries from near bankruptcy [27]. Biological control reduces energy use and is a non-polluting method of pest control. It has been shown that biological control of the pest is both privately and socially cost efficient and is a competitive alternative to the chemical method of controlling pests [28]. Energy conserving practices that would cause a switch to dryland farming in Hawaii also increase the use of pesticides and other chemicals. Thus positive improvements to environmental quality engendered by energy conserving practices in tillage, irrigation, and fertilizer use may be offset by a greater reliance on herbicides, fungicides, and pesticides in dryland farming.

AIR POLLUTION

Table 7 shows that agriculture is the source for 18.2 percent of air pollutant emissions in the state. The percent distributions in the table are for the sum of weights of sulfur oxides, particulate matter, carbon monoxide, hydrocarbons, and nitrogen oxide emissions. One can see that air pollution caused by agriculture is relatively a more significant problem in the rural counties of Hawaii, Kauai, and Maui than in urbanized Honolulu county. The sugar and pineapple industries both engage in field burning of crop residues after harvest. In addition, bagasse (sugar cane fiber) is also burned in sugar factories (stationary source) to produce electricity. Agricultural burning causes air pollution by emitting hydrocarbons, oxides of nitrogen and sulfur, and particulate matter [18]. In the immediate

Table 7. Air Pollutant Emissions Due to Agricultural Activities (in Percent[a] by Counties, State of Hawaii, 1980)

Source	State Total	Hawaii	Honolulu	Kauai	Maui
All sources	100.0	100.0	100.0	100.0	100.0
Agricultural fuel (stationary source)	6.5	15.1	2.0	13.7	12.9
Agricultural burning (non-stationary source)	11.7	19.3	4.3	24.2	25.4

Source: Hawaii Department of Health, Environmental Permits Branch, April 1988.

[a] Percent distributions for the sums of weights of sulfur oxides, particulate matter, carbon monoxide, hydrocarbons, and nitrogen oxide emissions.

Table 8. Air Pollution from Open Field Burning of Pineapple Trash and Stack Burning of Bagasse

Air Pollutant	Field Burning of[a] Pineapple Trash (in tons/acre)	Stack Emission Materials[b] from Incinerating Bagasse (in percent)
Sulfur oxides	negl.	0.015
Organic sulfer	N.A.	0.010
Particulates	0.093	N.A.
Carbon monoside	0.136	var.
Hydrocarbons	0.0487	N.A.
Nitrogen oxides	N.A.	N.A.

Source: P. Kasturi, Optimizing Land, Water, and Energy Use in Hawaii's Agricultural Production–1990 Under Multiple Energy Scenarios: A Linear Programming Approach, Ph.D. Dissertation, Department of Agriculture and Resource Economics, University of Hawaii, Honolulu, 1983.

[a] Information compiled from: W.-Y. Huang, A Framework for Economic Analysis of Livestock and Crop By-Products Utilization, in *The American Jorunal of Agricultural Economics, 61*:1, February 1979.

[b] Information compiled from personal communication with R. T. Webb, Environmental Superintendent, Hilo Coast Processing Company, Hawaii, letter dated June 4, 1980.

vicinity of burning, it can lead to photochemical air pollution and reduced visibility, thus becoming a significant aesthetic factor. The nature of pollutants and their quantities from the burning of pineapple trash and bagasse are listed in Table 8.

Open burning controls and stationary source regulations provide two ways of improving air quality in Hawaii. For new boilers the opacity of smoke must not exceed 20 percent [29]. By 1982 the sugar industry had already spent over $10 million to meet this regulation [14]. Some of these costs could be recouped if the ash resulting from the burning of agricultural residues could be reincorporated into the soils.

Research conducted on the field application of bagasse furnace ash and the ash from incinerated pineapple trash indicate economic benefits [18]. The ash from burned residues yield phosphorous, potassium, and a number of other secondary and micronutrients. Bagasse furnace ash also increases soil porosity improving yields. On the basis of commercial fertilizer prices in 1983, it is estimated that a ton of bagasse furnace ash was valued at $62.24 and a ton of ash from incinerated pineapple trash was valued at $41.88. Since nitrogen is completely consumed in the burning process, nitrogen pollution of groundwater is reduced to the extent that ash is substituted for commercial fertilizers.

POLICY CONSIDERATIONS

Policies based on taxes, research spending, improved soil conservation, and regulation are all applicable to the problem of reducing agricultural pollution in Hawaii. Taxes could be used to discourage excessive use of chemicals, fertilizers, and water. Research on mainland agriculture mainly directed toward field crops indicates that the relatively low price elasticities of these crops result in very low own price elasticities in the derived demand for their inputs. Thus very high and impractical taxes would be needed to discourage the use of chemicals and fertilizers [30]. The high taxes would result in increased cost of production and redistribute the geography of production. This may not be true of Hawaii crops. Pineapples, for example, compete with other citrus fruits and other growing regions in their final markets. Fruits in general, tend to have a higher own-price elasticity when compared to field crops such as soybeans or wheat. Furthermore, the Hawaii crop markets are distant and price elasticity usually increases with distance. Sugar cane competes with other growing regions, with sugar beets, and in the retail markets with sweeteners such as saccharin, corn syrup, and fruit juice flavorings. Additionally, retail products made with sugar frequently have own price elastic demands. While remaining inelastic in demand, sugar cane is likely to have a higher own price elasticity of demand than mainland field crops. Floriculture products, another major crop, are marketed worldwide and tend to have relatively higher own price elasticities than most field crops. On the input supply side, the high transportation costs of chemical inputs from the mainland is likely to raise their prices and, therefore, their relative own price elasticities relative to the inputs for the mainland crops cited. Another drawback to taxes, however, may be the practical problem of the legislative lobbying power of the agribusiness multinational corporate sugar cane and pineapple growers. There is understandable fear of the state legislators concerning taxing these industries. The business might leave the islands thereby creating considerable rural unemployment.

Regulation is often considered as an alternative to taxes to control environmental problems. It is particularly useful when there are many small producers that would make tax collection expensive and when users are only partial beneficiaries or cost bearers of the regulation. Sugar cane and pineapples produced on large plantation operations, hardly qualify on either of these counts. In addition, compliance with regulations also raises costs. Thus, regulation of pesticides and herbicides may encounter the same resistance from the sugar cane lobby in the State Legislature as taxes. Furthermore, only a small reduction in pollution may occur because farmers are likely to substitute an approved chemical for a banned one. This is particularly true if cost reducing alternatives to chemical use are nonexistent. As for irrigation practices, regulation combined with the implementation of withdrawal permits may be feasible at relatively low cost. Such regulation may mandate recycling of runoff or cleaning of water before returning it to the ground or streams.

The 1988 Census of Agriculture shows that only five agricultural places excluded from the farm definition had sixty-one acres in the conservation reserve program (CRP) [31]. Only one farm qualified for CRP according to the farm definition. While many farms in Hawaii produce products such as papaya that do not allow them to participate in this program, the large sugar and pineapple plantations have considerable acreages available that allow participation in this program. Although agribusiness firms manage their farms very efficiently trying to conserve top soil through recycling waste water and a system of reclamation ponds, soil conservation programs should extend to the sugar and pineapple fields as well as to the small farmers in Hawaii. The program needs to be restructured and incentives broadened taking into account the unique features of Hawaii agriculture.

Since regulatory or tax elimination of pollution in Hawaii agriculture raises production cost and reduces the competitiveness of local crops, research and development of alternatives to chemical applications appears viable. Funding for this research could come from the state government, local growers' associations such as the Hawaii Sugar Planters Association and the Pineapple Growers Association, and Federal sources. The objectives of the research is to develop cheaper alternatives such as biological predators, genetic engineering, biologically neutral soil coatings, and improved production practices. In the research programs environmental concerns need to be stressed. This can be accomplished by involving environmental and ecological scientists in crop breeding programs. Their input is vital for preserving and safeguarding the fragile ecology of the state which has evolved over the past five million years in complete isolation. Externalities in agriculture can be minimized when the full potential of biotechnologies and genetic engineering is harnessed to develop varieties with increased disease and pest resistance, drought resistance, higher yields, reduced leaf growth, and shortened periods of maturity. Irrigation research could explore such ideas as improved drip systems, drip systems that are compatible with heavy equipment currently in use, and means of recapture and recycling of runoff from the fields. Soil could be protected from compaction by developing lighter forms of field equipment. Dissemination of the findings of the research would be relatively easy because of the large corporate plantation nature of Hawaii agriculture. The people who need the information most could easily be contacted individually and the information spread quickly.

CONCLUSIONS

This article has enumerated a number of environmental concerns related to Hawaii agriculture. Although pollution from this sector is not as severe as in other parts of the United States, it currently does have a negative impact on Hawaii's tourism industry, flora and fauna, and the health of residents. Vigilance on the part of government, crop producers, scientists, researchers, consumers, and activist groups can greatly reduce the scope for harm to Hawaii's fragile ecology due to crop production activities. Research quantifying and qualifying relationships between production agriculture and environmental consequences will lead to a deeper understanding and more efficient solutions.

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