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POTENTIAL ECONOMIC AND ENVIRONMENTAL COSTS TO THE PUERTO RICAN GOVERNMENT FROM ENERGY CANE TECHNOLOGY

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WITH

CINDY GINES

AUGUST 5, 1983

REVISED - JULY 1984

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO · U.S. DEPARTMENT OF ENERGY

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FOREWORD

This research was performed under appointment to the Faculty Research Participation program administered by the Oak Ridge Associated Universities for the U.S. Department of Energy. Ginés wrote most of the section on pesticide use and impact. Gottfried wrote the other sections.

ABSTRACT

This study assumes that energy cane will be grown on the 40,000 acres allocated to sugar cane under the updated Plan for Modern Agriculture. The paper compares the direct and indirect costs to the Puerto Rican government from present sugar cane cultivation on these acres to that from energy cane.

Although the energy cane concept utilizes the growing of cane on prime and marginal lands along with short-rotation crops, this study focuses on the growing of energy cane on prime agricultural land.

Sugar cane cultivation has been declining in Puerto since its peak in 1951/52, mainly due to high costs of production. The Sugar Corporation has responded by supporting the sugar industry in three major ways: by running the mills, by the refacción system (an elaborate system of production loans), and by offering input services. Although the energy cane concept assumes no need for government involvement, the paper assumes that, for the near future, the present government intervention in the sugar industry will continue.

Energy cane technology differs from the technology used currently on the island in its use of double seed instead of single seed, much larger applications of nitrogen fertilizers, subsoiling, land leveling, virtually no use of pesticides, and different harvest machinery. It can be grown on a "conservation" basis which, for every other crop, utilizes no inputs other than harvesting. There remains substantial confusion over the extent to which the sugar mills must be altered to accommodate energy cane (and the short-rotation crops). Similarly, some doubt exists whether weather and soil conditions will permit the eight-month grinding

season advocated by energy cane proponents. Some of the confusion over the milling stage undoubtedly arises from the emphasis in the energy cane approach on the multiproduct potential of cane, not on sugar production. Current discussion focuses on the use of cane for production of high test molasses (HTM), fiber for boiler fuel in electricity generation, and, possibly, some sugar production.

When the differences in inputs in cane cultivation are considered, energy cane production would cost the government, in very rough figures, about $700,000 more per year than current sugar cane. However, assuming yields of 26 and 80 tons/acre for sugar and energy cane respectively, costs to the government per ton of cane would fall from $1.89/ton to $0.84/ton. The differences in milling costs remain unclear. Given the larger revenues from higher yields as well as the multiproduct potential of energy cane, higher government revenues appear likely. With lower costs a clear possibility, the potential exists for decreasing the losses of the Sugar Corporation or for showing a profit. The larger ramifications of the use of energy cane technology in terms of greater employment and potential stimulus to other industries largely lie outside the scope of this paper (the effect on the rum industry is examined later, however).

The paper examines three indirect effects of energy cane: the effects of increased fertilizer use on streams and rivers, the effects of decreased pesticide applications, and the impact of HTM production on the local rum industry. It appears possible that nutrient levels in Puerto Rico's streams and rivers could increase due to the growing of energy cane. The extent of a potential increase in water hyacinth growth cannot be predicted because of the lack of scientific information. Due to the interaction of changed nutrient levels, hyacinth growth, and lower dissolved oxygen level, water life could be affected both in streams and, possibly, in the ocean. This could affect fishing revenues and government taxes. However, the latter effect should be small due to the low level of taxes paid by fishermen. The direction of the change is uncertain, however. By affecting the evapotranspiration rate positively or negatively, water hyacinth growth could affect the economy and tax receipts via water availability. Hyacinth growth could increase the potential for schistosomiasis and therefore, the level of disease control expenditures, as well as occasionally cause flooding. The main problem hindering estimates on the impact on the government remains the lack of scientific studies and data.

The switch from standard cane to energy cane implies a large drop in the use of pesticides. The three most commonly used pesticides in sugar cane cultivation possess low toxicity. At least one is nonpersistent. Data concerning occupational health problems and environmental contamination from traditional cultivation are inconclusive. Thus, although the switch to energy cane should decrease governmentally-borne medical expenses due to present pesticide use, the size of the savings cannot be estimated without better data and more research.

The extent of the environmental damage caused by the discharge of rum slops with and without treatment requires further study. The switch to the use of HTM , an output of energy cane, should reduce environmental damage. The extent of the reduction remains unclear, as does the economic significance of such a reduction.

The most important effect of HTM use may revolve around its potential impact on rum sales and/or profitability. Most likely the rum industry will lower costs of production and raise its profit margin by maintaining the same level of prices. The use of domestic HTM should enable the industry to produce a higher quality rum with less risk of input unavailability. However, even with further studies and a large pilot-run using HTM to obtain more information about potential cost savings, it will be difficult to predict the industry's behavior. Therefore, firm predictions as to the impact of HTM use on the rum industry, the source of 1/7 of the Commonwealth's annual government revenue, may prove impossible.

The paper ends with a series of recommendations for further study.

INTRODUCTION

Although much has been written on energy cane in Puerto Rico, to date little has been written on the costs to the[1] Puerto Rican government if it were adopted. Even less has been written on its environmental impact and what this might cost the government. This paper attempts to fill both of these gaps. Much necessary information is still lacking, particularly in the environmental area. Consequently, this paper attempts to point out any known costs and to bring attention to those areas requiring future research.

Establishing a baseline to which energy cane can be compared has proven rather tricky. First, sugar cane in Puerto Rico is declining. Consequently, both the actors in the industry and the production parameters change over time. Second, the updated Plan for Modern Agriculture for Puerto Rico (59) calls for a modern, well-managed sugar industry which currently does not exist. Energy cane could be compared to this hypothetical modern sugarcane industry. However, the latter has not been described in any great detail. Third, energy cane could be compared to alternate crops such as vegetables which could be grown on the same land. However, the vegetable industry also represents more of a proposed rather than an actual industry. So, none of these three possibilities present a firm basis for comparison to energy cane, which itself is a hypothetical industry of the future.

For the purpose of this paper energy cane will be compared to sugarcane as it currently is produced in Puerto Rico. However, the

[1]See (37) for the only paper to the author's knowledge on the environmental impact of energy cane.

paper will assume that the cane is being grown on the 40,000 acres of land alloted to sugarcane under the updated Plan. Both a modern sugarcane and energy cane industry could result in similar direct costs to the government. Differences in environmental costs would depend much upon the extent of differences in pesticide, irrigation, machinery, and fertilizer usage.

The paper consists of two main divisions. The first compares energy cane to current sugarcane to compute a rough estimate of the differences in direct costs to the government due to adopting energy cane. Therefore, this division examines government incentives for sugarcane production and, assuming this structure continues, attempts to compute the differences in the cost of such incentives between the two cane industries. The second division looks at differences in indirect costs to the government from both industries as a result of differences in their environmental impacts. Thus, it examines the effects from nutrients in rivers, pesticides, distillery wastes, and other environmental factors. The study ends with a section summarizing the paper and providing some conclusions on the cost of energy cane.

DIRECT COSTS

This section outlines the potential direct costs to the government of Puerto Rico from establishing energy cane on the forty thousand acres set aside by the updated Plan for Modern Agriculture. The figures given here lack the precision on an in-depth study. However, they can provide some initial insights into the types of costs involved and their possible order of magnitude.

The section first provides a brief description of the sugar industry in Puerto Rico. It then summarizes the differences in technology as currently practiced by sugar growers in Puerto Rico and as envisioned for energy cane. Next, it discusses the differences in cost to the Puerto Rican government as a result of adopting energy cane instead of sugarcane. The section ends with a summary.

1. Description of the Sugarcane Industry in Puerto Rico

The following paragraphs describe the decline of the sugar industry, the reasons for its decline, the relationship of the Sugar Corporation to cane farmers, and the assistance provided by other government agencies. This description provides the background necessary for an understanding of the institutions and history which would affect energy cane.

a. The decline of the industry

During the colonial years Puerto Rico had as many as 560 sugar mills operating on the haciendas of their owners. Later, large U.S. Corporations gathered the haciendas into large farms serving one large mill or central. In the late 60's and early 70's the Puerto Rican government bought both the land and the mills of the now ailing industry. The latter has continued to decline to the present day. On July 8, 1983 the Puerto Rican government's Sugar Corporation divested itself of the last of its cane lands so that they once again rest in private hands. The Sugar Corporation, however, owns the five sugar mills still in operation (6,36).

A few statistics further illumine the decline of the sugar industry. Having peaked in 1951/52 with 391,763 cuerdas of cane harvested (one cuerda equals 0.99 acres) by 1983 only approximately 70,000 cuerdas of cane remained of cane remained in production. Cane production fell from 12,537,000 tons to 2,236,000 in 1979/80. Raw sugar production peaked in 1951/52 with 1,360,000 tons of raw sugar produced compared to only 175,000 tons in 1980 (31, p. 41).

The main reason for the decline at the sugar industry appears to be associated with Puerto Rico's high costs of production. Various experts refer to the following causes of high cost production: the lack of agricultural workers due to migration, resistance of unions to mechanization, strikes, delayed mechanization using the wrong equipment, rapid mechanization without a logical transitional period, lower cane yields and lower sucrose contents of cane (which are aggravated by forced mechanization in the field), federal labor laws, excessive labor use by the Sugar Corporation as means of providing employment, rising irrigation, machinery, maintenance and transportation costs due to higher energy costs, inadequate fertilizer application due to higher prices, lower pesticide usage, deteriorating attitude of farmers toward cane, government bureaucracy, short-sighted policies, politics, and poor educational levels of farmers (4,6,36,46). In the milling stage many ascribed decline to factors such as dirty cane resulting from the mechanized harvest, high energy prices, and EPA-required wet scrubbers and water treatment facilities (4,36, for example). Deteriorating equipment and excess capacity are also mentioned (47). Finally, Romaguera blames the refineries' high costs on three factors. First, the intermittent grinding of cane due to field mechanization problems interrupts the continual refining process and thereby causes excessive fuel consumption. Second, the mills supply poor quality raw sugar. Finally, the refineries cannot utilize second grade liquors because they make only one grade of sugar (46).

b. Relation between the Corporation and the colonos

The Commonwealth government's policy of maintaining the declining sugar industry has led to several kinds of support. The Sugar Corporation plays the major role in this involvement, although other government programs contribute.

The Sugar Corporation supports the industry in three major ways: 1) by running the mills, 2) by the refacción system, and 3) by offering input services (see Table 1). First, the refaccion system consists of a program whereby the central, or sugar mill, grants the landowner (colono) a loan of about $20/anticipated ton for harvest and transportation. The loan consists of an account at the mill upon which the colono may draw to pay for any inputs he wishes. For instance, should a colono wish to buy fertilizer, the central will issue a voucher to a fertilizer company for the desired amount. When the harvest is completed, the central transports the cane to the mill and produces sugar and blackstrap molasses. Of the sugar produced 63% goes to the farmer and 37% to the mill. Both the mill and farmer sell sugar at a price at least equal to the USDA support price of 21 cents/pound. The farmer receives from the mill the value of his cane minus the amount lent to him, plus interest at the market rate. For every ten cents that the sugar price exceeds the support price of 21 cents, six cents go to the farm laborers and four cents go to the farmer. Similarly, for every ten cents the price exceeds the supported price the mill gives 6 cents to its workers and keeps 4 cents.[1]. A similar arrangement exists for molasses. The government

[1] With a constant sugar share, generally weak sugar prices, and rising cost, mills have steadily lost money.

of Puerto Rico then transports the sugar to New York at its expense (drawn largely from 36).

Colonos receive additional government support in the form of subsidized inputs. The Corporation provides complete machinery services to farmers, charging them only for labor and fuel. No charges are made for the machinery itself, transportation to the site, breakdowns, or loss of time. Farmers also receive seed at reduced price.

Other governmental services provide support to sugarcane growers. The Commonwealth pays each farmer, whatever the crop, sixty cents per man-hour of labor used on his farm. In addition, farmers receive loan and price incentives for the purchase of new machinery. The USDA supports the price of sugar, as mentioned previously.[1] In some areas the Commonwealth provides irrigation, at a charge of $6/acre foot compared to a true cost of $36/acre foot (6). However, one should note that whereas growers of other crops may buy fertilizers and pesticides at reduced prices, colonos may not.

This institutional setting provides the framework within which the potential impact of energy cane on the government's expenditures can be examined. However, before one can assess this impact one must understand the differences in technology between sugar and energy cane. Consequently, the following sections will compare and contrast the two technologies.

2. Differences between Energy and Sugar Cane Technology

This section first compares and contrasts the growing and harvesting of both forms of cane. It then briefly discusses the milling of cane and the products expected from it in each technology.

[1] The updated agricultural plan proposes a Commonwealth support price of 25 cents per pound.

a. Conceptual overview

The energy cane concept involves growing a variety of plants under differing conditions in order to provide a multiproduct output on a year-round basis. A cane with higher fiber content, lower sucrose content, and much higher yields per acre than normal sugarcane would be grown on land suitable for mechanized agriculture. In addition, other species or "wild" sugarcanes would be cultivated on land previously considered marginal due to contour, aridity, salinity, or acidity. "Short-rotation" crops such as Sordan 70A which mature in eight to twelve weeks after seeding would fill in gaps in food crop rotations and provide four to six tons of dry matter. Because Puerto Rico normally experiences a rainy period from mid-August through November, grinding of cane would extend from December 1 through July, longer than the current five to six month period from mid-January to late June. The sugar mill would generate electricity over the entire year by burning bagasse during the eight month grinding season and mill-dried bagasse and solar-dried grasses during the remaining four months. Because the bulk of sugar recoveries would be made during the period February-May, the mills essentially would operate as dewatering sites for sugarcane fuels during the other months. The high-fiber sugarcane would provide not only fuel for electricity generation and mill operation but a source of chemical feedstocks, sugar and molasses (1,53).

For several reasons, the pages below focus on one aspect only of the energy cane concept: the growing of the high-fiber sugarcane on prime agricultural land. First, the direct costs to the government of Puerto Rico from energy cane cultivation will come mainly from this aspect of the program as long as the government maintains the current support for sugarcane production. Second, relatively little study has been done on the cost effectiveness of planting various biomass crops on marginal land. Given the cost of labor and of transportation, such a proposal may prove generally uneconomical. Finally, most discussion currently focuses on growing modified sugarcane on quality land. Relatively few studies have been performed on growing short rotation crops for integration into factory operations in Puerto Rico.

b. The growing of cane (6,39)

Although species selection and breeding have produced a better yielding cane in terms of biomass, the main difference between energy cane and sugar cane lies in management and goals. In the case of energy cane, growers attempt to produce as much biomass as possible irrespective of sugar content. So, they encourage the cane to grow from the moment of seeding to harvest. For sugarcane growers strive for high sucrose content and try to stimulate the cane to store sugars instead of producing fiber.

The following paragraphs outline step-by-step the differences between current sugarcane practice on the island and energy cane cultivation on field plots in Lajas and on the experimental farm in Hatillo. One should note that many of the management techniques used for energy cane would improve the yields of sugarcane also.

Seedbed Preparation

A good seedbed promotes good crops of any cane. The better seedbed preparation for energy cane may explain much of its higher yields when compared to sugarcane in Puerto Rico (80-100 + tons/acre vs. 25 tons/acre).

Typically, the first step in conventional sugarcane production in Puerto Rico involves the use of the disc harrow (called a "plow" on the island) which basically cuts the earth, produces large clods, and turns them on their sides. The harrow passes seven to eight times in each of two perpendicular directions. The field is then furrowed.

Energy cane uses the disc harrow for one pass only to loosen up the soil. Then a moldboard plow with three steps turns over the soil. This brings up nutrients from below. A rotavator then passes over the field to pulverize the soil and organic matter, providing a finely textured level soil. This seedbed permits more air, water and nutrients to reach the roots and, therefore, promotes better root development.

When preparing a field for the first time in energy cane. the farmer uses a plane to level it so that the seedbed is perfectly flat. Although planing would be optimal for sugarcane also, most farms have not utilized it. After planing the soil is furrowed for planting.

Planting

Cane sprouts from the roots of a previously planted crop. Consequently, farmers allow cane to regenerate for several "ratoon" crops before starting over and reseeding. When farmers seed, they place fertilizer in the furrows and lay lengths of cane on top. Manual labor performs the planting in both canes. In the case of sugarcane 120 pounds of nitrogen per acre is applied at this time, with no further fertilizer applications. Workers place only one row of cane in the furrow and generally do not cut it into smaller pieces. In the case of energy cane workers first cull out only the best cane for seed and then place <u>two</u> rows in the furrows on top of 200 pounds of nitrogen fertilizer per acre. Laborers then chop the cane into approximately six-inch pieces in order to provide far more germination than under typical conditions (cane typically sprouts only at the first node below the end of the stalk). In both cane technologies the seeds then are covered over. In the case of energy cane the field returns to its flat, level condition whereas, in the case of sugarcane, it remains furrowed.

Irrigation

Cane responds well to water as long as the soil is well drained (7). Standard cane generally receives water as needed to supplement rainfall, so that on the average it obtains a total of around 2.5 to 3.0 acre feet of water from all sources. Growers irrigate by directing water though the furrows.

In the case of energy cane Alexander points out the importance of irrigating at least right after planting to insure the highest germination rate. A dry spell at this time could ruin the crop. This initial irrigation utilizes the overhead method. Subsequent irrigation utilizes border irrigation which is far cheaper than the furrow method used on sugarcane. Energy cane requires about seven acre feet of water to produce high yields. On the semi-arid south coast this means that 3.5-4.5 acre feet of irrigation water must be provided. The water is applied in treatments of 2-3 acre inches at a time, each acre inch of water yielding approximately 1-1.2 tons of green cane/acre. Irrigation continues until just before harvest in order to foster continual growth without presenting harvesting machinery wet soil conditions (6).

Fertilizer

As noted above energy cane utilizes about 200 pounds of nitrogen fertilizer at the outset compared to 120 pounds for sugarcane. However, energy cane receives two additional applications of 100 pounds each every four months compared to no further applications for cane. Total fertilizer usage, therefore, is 400 pounds of nitrogen for energy cane compared to 120 pounds for standard cane.

Subsoiling

Subsoiling is a practice which stimulates rooting and aerates the soil. It is regarded as an essential part of the energy cane process but is not used by the Sugar Corporation. When a subsoiler is drawn through the ground, the implement cuts through the earth two feet underground on either side of the plant row and horizontally toward the center of the row. The plant crop is subsoiled twice (two passes), whereas ratoon crops are subsoiled once after shoots first appear. Subsoiling aerates the soil and cuts some of the cane roots. The latter stimulates further root production.

Weed Control

In typical sugarcane culture today in Puerto Rico farmers utilize a variety of herbicides. Typically diuron (Karmex), Dalapon (Dowpon), 24-D, Metribuzin, and Amertryne are used, with some others. The USDA recommends the application of three to four pounds per acre of herbicide after planting and another equal application about two months later (52). Actual usage appears to vary by region. Most people agree that, with the Corporation's divestiture of cane land, pesticide usage (as well as fertilizer usage) has fallen as private farmers attempt to cut costs. Singmaster estimates that currently 1/2-2/3 of all farms receive one application, 1/4-1/3 receive two applications, and 1/4-1/3 receive none (52) (See data in section on pesticides under Indirect Costs).

Energy cane differs markedly from sugarcane in that virtually no herbicides are used. The rapid formation of a dense canopy generally shades out any weeds before they can present problems. A type of morning glory presented some difficulties in Hatillo because it climbs the cane plant and thereby competes with it. However, cultivating with machinery controlled the weed more cheaply than herbicides, thereby avoiding the potential problems of the herbicide's slowing cane growth.

Insect Control

Various insects attack the cane plant, among them aphids and two species of the white grub (gusano blanco): the vaquita (responsible for 2/3-3/4 of gusano blanco infestations) and the phytophagia (52). The grub attacks roots and seriously affects sugarcane on the south coast. Farmers used Aldrin successfully to control the grub prior to the chemical's being banned. No successful substitute has been found. Sugarcane growers occasionally use Diazinon and Carbofuran for the grub and disyston for aphids. However, insecticide use is uncommon today (52).

Energy cane grows so fast that it outpaces the grub, the latter attaining its peak population density in the cane root before the cane reaches its peak. In fact, the grub stimulates further root production by eating some of the roots. For each damaged root the cane sends out around two more roots. Consequently, energy cane requires no pesticides to control the grub (6).

Energy cane may require the use of some malathion in the first two months when shoots appear. During this time shoot borers may adversely affect growth. However, in the last three years of cane experiments Alexander stated that it never had to be used (6).

Harvesting

Typical sugarcane harvesting in Puerto Rico utilizes the Claas combine which strips the cane of much of the trash (dead leaves). The Claas costs $100,000 and requires a crew of three persons. It breaks down often (and therefore often comes accompanied by a mechanic). The Claas automatically feeds the harvested cane into an accompanying vehicle. It also requires careful attention on the part of the operator to cut the cane stalk just above the point where it comes out of the ridge of the furrow. Because of irregularities in the ridges and operator behavior, cuts often are too high or, worse, too low, allowing dirt to be picked up with the cut cane.

Energy cane utilizes the conejo or v-cutter because high yields from this cane tend to be beyond the capacity of the Claas. The conejo costs around $40,000 and breaks down less. However, it leaves the cut cane on the ground. Consequently, a mechanized push rake must be used to push the cane into a pile which then can be loaded unto vehicles with a grab loader. The use of the push rake increases the amount of dirt in the cane and raises milling costs accordingly. However, the flat seedbed of energy cane mitigates this problem somewhat. Careful use of the rake may allow even lower dirt contents. Alexander points out also that workers could be used to pile the cane so that clean cane then could be picked up by the grab loader (6). All cost calculations, however, have utilized the push rake. One available option would be to reduce inputs (and costs), obtain lower yields, and then use the Claas.

A major difference between the two cane harvests consists of the burning of trash. Most sugarcane growers burn their fields prior to harvesting to minimize trash. Such burning does not affect sugar content as long as harvest follows in two to three days. Harvesting later than this allows mold to form and to penetrate the stalks through fissures caused by the burning (harvest delays makes this a serious problem today). With energy cane trash is a desirable commodity. So, trash remains on the stalk. Although it presents a more formidable harvesting challenge, it also allows more flexibility in harvest timing. However, as one observer has pointed out arson in cane fields is common. Many individuals whose homes adjoin cane fiels burn the field as a preventive measure. Knowing that the field will be burned anyway and that someone else may burn the field while they themselves are asleep (posing a fire hazard to their home and lives), they burn the field before someone else does (36). This poses a problem for energy cane which derives a substantial portion (e.g. 12%) of its biomass from the detached and attached trash (for figures relating to the importance of trash, see Tables in 3).

Crop Strategy

After the initial seeding canes are harvested 12 or 18 months later. Then the cane sprouts from the remaining "crown" for another crop known as the "ratoon" crop. This cycle of sprouting and harvesting can continue indefinitely. However, ideally canes would use an average of three ratoon crops, although sugarcane in Puerto Rico often is allowed to ratoon more. After three ratoon crops the cane would be reseeded to insure better yields.

Although some varieties of energy cane give highest yields on an 18-month growth cycle, the need to fit crops into the harvesting/milling season limits the number of 18-month crops which can be obtained.[1]

From a different perspective energy cane presents a particularly interesting opportunity: conservation agriculture. Under this system the plant crop and second ratoon are cultivated intensively, whereas as the first and third ratoons are cultivated with no inputs except for harvesting. At Hatillo researchers grew second generation energy cane through the first ratoon crop under this system. The intensively grown plant crop yielded 125 tons/acre year of whole cane at a cost of $9.82/ton. The conservation culture on the ratoon yielded 53 tons/acre year at a cost of $7.47/ton. This system provides good yields as well as debt relief every two years to farmers. However, the intensive culture has to be repeated every other year. Also, it requires more land to obtain a given amount of biomass than does intensive culture (5).

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[1] According to Lewis Smith, machinery capability probably constitutes the critical constraint.

Conservation culture, however, should present fewer environmental effects because of the lower inputs.

Summary

Much of the higher yields of energy cane can be attributed to the intensive seedbed preparation it receives. Energy cane uses double seed instead of single seed, much larger amounts of nitrogen fertilizers, subsoiling, virtually no herbicides or insecticides, and different harvest machinery. It can be grown on a "conservation" basis which, for every other crop, utilizes no inputs other than harvesting.

c. Milling

Few firm statements can be made about the differences between milling sugar and energy cane. The extent to which current mills need to be altered to accommodate the more fibrous cane which includes tops and trash remains a matter of discussion and speculation. For instance, cane leaves tend to wad up, thereby hindering the milling process. Also, tops contain simple sugars such as fructose and glucose which form a rubbery film in the evaporation pans and make the extraction of sucrose much more complicated (36,47). Papers on the milling of energy cane can be found in the Symposia proceedings dealing with energy cane (9 and 18). See also section I-3.b below. Until a large pilot milling of energy cane is performed no one knows how well the present mills will handle it.

There appears to be some confusion in the discussion of the topic because the goal of energy cane is to provide a material which has multiple uses, one of which is sugar. Many people within the present cane industry view cane as providing sugar, along with fiber which may be a useful byproduct. Energy cane advocates view cane as a plant capable of producing several products which may or may not include sugar. Consequently, some industry people may complain about the milling of energy cane making sugar extraction more expensive, for a variety of reasons, because they view sugar as the primary product. Viewing fiber and fermentable solids as primary products, instead of sugar, might render these criticisms irrelevant or less important.

Energy cane advocates currently seem to be proposing three products for consideration in Puerto Rico: high-test molasses (actually a cane syrup with none of the sugar removed), sugar, and fiber. The molasses would serve as the primary input for the rum industry, replacing the less desirable blackstrap molasses which is the byproduct of sugar production. When high sugar prices permit, some "first strike" sugar could be produced for domestic consumption. Finally, the bagasse, or cane fiber, would be sold to the electric power company as boiler fuel, replacing fuel oil. Although sugarcane could produce all of these products, as well as the others which energy cane could provide (though not in the same quantities), high-test molasses (HTM) and fiber are integral parts of the current energy cane approach. They are not so in the sugar industry. Consequently, production of fiber and HTM will be considered as part of the energy cane technology even though they could be produced with standard cane.[1] The questions of marketability of these products and of their prices lie outside the scope of this paper.

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[1] For a more through discussion of the many uses of cane, and of the energy cane approach, see 2, 45, 49, 53.

3. Differences in Cost to the Commonwealth Government

The energy cane concept itself is designed for private enterprise and is designed to be profitable. It does not presuppose government support. However, given the historical sugarcane situation in Puerto Rico, energy cane probably will receive support until the industry can demonstrate that it can stand alone. Consequently, the following section analyzes the costs to the Puerto Rican government from the establishment of energy cane given the present governmental involvement in the sugar industry.

The paragraphs below consider the direct costs to the government. Because the industry's impacts on the environment and the rum industry will affect the government indirectly, these considerations are considered separately. Indirect effects such as increased employment from cane production which reduces welfare or other governmental expenditures and increases tax revenues will not be considered. Neither will the paper consider possible differences in the multiplier effects of the two industries nor possible differences in their effects on economic growth.

a. Methodology

The approach taken below constitutes only a first approximation. The methodology consists of examining the differences in the amounts of inputs used in energy cane most recently and in standard cane as grown by the Corporation.[1]

A more thorough approach would involve utilizing input figures from the centrales in the areas designated by the Plan for sugarcane. Even then comparisons might prove less than reliable because, while

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[1] The comparison relies heavily on interviews with Alex Alexander, 6.

standard cane practice may vary regionally in response to different conditions, the energy cane figures are based only upon two sites in Lajas and Hatillo. Further, it is difficult to disaggregate several key elements in the energy cane figures, such as labor. For instance, harvest labor is subsumed within harvest costs, making it difficult to break out labor figures, skilled and unskilled, into a separate category. Thus, while the current approach is very rough, hopefully it provides an approximate estimate of the sort of numbers involved. It should be noted that politics and bureaucracy being what they are, it is difficult to know what the costs of energy cane under the current institutional arrangements might actually turn out to be. Moreover, should the crop prove sufficiently viable the roles of the Corporation and other government agencies could be altered in such a way as to remove government support from the industry altogether. Such a change would save the government a great deal of money when compared to the large losses which it has endured.[1]

Following the updated Plan (59), the paper assumes that the following acres (cuerdas) are allocated to sugarcane cultivation (see Map 1):

Central Coloso y Plata:	Aguada - 6,000
	Añasco - 6,000
	San Germán - 2,000
Central Roig:	Humacao - 5,000
	Yabucoa - 6,000
Central Mercedita:	Ponce-Guayama - 15,000

[1] Annual losses have been over $60 million in recent years. Legislation now requires losses to stay below $30 million annually.

The above four centrales (sugar mills), one less than at present, will serve these areas. Only Mercedita will refine sugar.

b. Growing of Cane

Given the set of governmental incentives to the sugarcane industry, Table 2 outlines the differences in cost to the Commonwealth government of supporting 40,000 acres of sugarcane (as currently produced) or of energy cane. The following paragraphs explain the calculation of the items in Table 2 and then discuss their significance.

In calculating the differences in seed costs the table assumes that the true cost of seed is $18/ton. Energy cane utilizes about 5 tons per acre compared to standard cane's 2.5 tons/acre. Assuming that the seed is sold at half of its true price, then, for instance, sugarcane costs the government $900,000 over a three crop cycle (2.5 tons/-acre x $9/ton x 40,000 acres). Spread over three years the yearly cost for sugarcane seed amounts to $300,000. Similarly, energy cane seed costs the government twice as much because of double seeding.

Only energy cane utilizes subsoiling, which costs $10/acre for a ratoon crop. The plant crop requires two passes with the machine and more time because the rows are harder to see. Therefore, assume arbitrarily that the plant crop costs $18/acre to subsoil. Then, over a three crop cycle subsoiling averages to $12.66/acre. If 60% of the cost is covered by the government (capital, transport, repairs), then subsoiling costs is almost $304,000 ($12.66/acre x 40,000 acres x .60).

Table 2 shows no added water expenditures on the part of the government. This result comes from the following reasoning. Of the areas under consideration only the Ponce-Guayama area is served by the government irrigation system. The other areas supplement rainfall, if at all, with groundwater. In the Ponce-Guayama area the government has only been able to supply 40-50% of the 3-foot allocation. In addition, the system is in very bad condition. Consequently, most of the land in the area uses wells or private reservoirs to supplement (8). With energy cane it is reasonable to assume that additional water requirements would come from these supplementary sources, not from the government irrigation system which already falls short. Moreover, most of the system's costs occur regardless of whether water is delivered or not ("fixed costs") (8). Consequently, the government would not incur additional expenses due to energy cane's irrigation requirements.[1]

The government could opt to repair and expand the present irrigation system. Such a system would be useful for sugarcane, energy cane, vegetables, or any other crop requiring water other than natural rainfall. The updated Plan calls for the government to install such a system at a cost of $1300/acre for laying pipes to bring water to the site. Leveling the land and improving drainage on the east and west coasts would cost $600/acre there (energy cane advocates include the cost of land leveling among farmer's costs) (60). Such governmentally-borne expenses would not be the direct outgrowth of an energy cane program but rather of the decision on the part of government to support a modern agricultural system. Consequently, these costs are not

[1] The $1,512,000 figure was obtained by multiplying the 3 foot allocation times 15,000 acres to obtain the number of acre-feet the system is suppose to provide. Multiplying this figure by the government's cost of $36/acre-foot yields the total cost of $1,620,000. Assuming 1.2 acre-feet of the 3 allocated are delivered, the system recoups $6 acre-foot in fees, yielding a net cost of $1,512,000.

included here as a cost of energy cane adoption.[1]

Finally, to calculate labor costs for energy cane the day labor data from first generation cane (2, Table 19) are used because these include two ratoons, whereas intensively cultivated ratoon crop data for second generation cane is unavailable. For 200 acres the data show an average of one man-year of labor (2016 man-hours) used per year over the three year cycle. Energy cane's labor costs exceed those of standard cane, particularly in seed selection and planting.[2] This implies that standard cane utilizes 1260 man-hours (1.6 x 1260 = 2016) for 200 acres. So, the two canes average 10.08 and 6.3 man-hours per acre respectively. The government pays farmers $.60 per man-hour of labor employed. Thus, in the case of sugarcane labor would cost the government $151,000 (6.3 man-hours/acre x 40,000 x $.60/man-hour).

When the yearly figures for these two canes are summed and their differences taken, the production of energy cane costs the government approximately $695,000 more per year than sugarcane. When these figures are viewed in the light of the $60-80 million losses of the Corporation, they are not large. Should farmers pursue a conservation strategy of farming intensively in the first and third years, allowing the first and third ratoons to grow on their own with no inputs, then these costs would be incurred twice over a four year cycle. This would halve the

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[1] It should be noted that increased water usage on the south coast for energy cane might conflict with other agricultural uses, particularly if groundwater must be used as the principal source. William Allison and Ferdinand Quiñones would be helpful in addressing this question.

[2] Day labor is used in the selection and planting process, as well as in other stages of production.

costs to the government (as well as lower output), bringing the yearly costs to $247,500.[1]

One might note in passing that the cost to the government of energy cane may be very similar to that of sugarcane grown as envisioned by the Plan. Both use modern management techniques.

b. Milling and refining

The question of cost differences in milling and refining for the two types of cane remains one of speculation. This results from the lack of experience in milling energy cane and the uncertainty as to the exact products which would be produced. Some considerations with respect to milling follow.

With the greater quantity of bagasse which is produced more boilers will be needed to produce energy at the mill. However, the electric company may not need the energy at this time. So, storage of bagasse could be considered. However, bagasse's tendency toward spontaneous combustion makes this difficult. Pelletizing it could solve the storage problem but would require different boilers (47). Lewis Smith points out that bagasse is cheaper than oil. Accordingly, PREPA (Puerto Rico Electric Power Authority) should burn it instead of oil even when megawatt demand is steady or declining. Bagasse storage therefore poses little problem. To insure efficient operation, energy grasses would have to be available to provide boiler fuel when bagasse is not available. Grass can be stored in the fields (54).

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1 As noted earlier, should the government pay for irrigation infrastructure this could cost $35 million.

According to one source the current mills generally are so outmoded and inefficient that it would be nonsensical to include them in an energy scheme. While useful for demonstration purposes, they need to be rebuilt with high pressure boilers, perhaps as part of a joint venture with the electric company (47).

From the acreages given in the Modern Plan it would appear that at the 40 tons/acre assumed therein Coloso and Plata would be underutilized whereas Roig and Mercedita would be operating at acceptable levels. If the greater yields of energy cane are thrown into the picture, it is unclear whether Roig and Mercedita would have sufficient capacity to handle the harvest (47).

Weather plays an important role in the grinding sequence. Although there is no rainy season in Puerto Rico, there tends to be a rainy period from May to November (48), p. 11). Grinding needs to start as early in January as possible to insure that harvest machinery can enter the fields and that the cane is dry. Although some energy cane advocates claim that the cane can be harvested wet, whether the harvesting machines could enter fields outside of the short present grinding season without severely compacting the soil and tearing up the fields remains questionable (see 7). Therefore, the proposed extension of the grinding season to eight months on the part of some energy cane advocates would appear to need further study. Such a season would seem most possible on the semi-arid south coast. However, the probability of success in the other cane areas suggested by the Plan would appear doubtful. Thus, the extent to which energy cane would lower unit costs by making more efficient use of existing idle capacity needs to be examined carefully (36,47).

As mentioned previously, leaves tend to form wads which would up the grinding mechanisms. Romaguera points out that the use of a shredder prior to grinding would solve this problem as well as prepare the cane better for grinding (47). This, of course, would alter costs.

From Lewis Smith's perspective energy cane's higher fiber content does not represent much of a problem. The addition of attached trash and tops increases fiber contents from below that of conventional cane to only slightly above. He cites J.H. Payne as not considering this to be a large problem. Moreover, the cleanlines of energy cane should more than compensate for fiber-induced problems inasmuch as noncombustibles (dirt, stones) constitute as much as 18% of Puerto Rican sugarcane content (54). It also can be pointed out that cane free of the dirt associated with present cane would not require expensive washing prior to grinding.

The problem of the effect of tops on sugar extraction must be addressed with respect to costs. This problem will affect the decision of which goods to market and which capital expenditures to make, thereby influencing costs.

Refining costs will depend on the quality of raw sugar produced, the extent to which continuous operation can be achieved, and the amount of raw sugar produced from the cane. The latter depends on whether HTM supplants sugar production totally or whether some sugar and a high quality molasses (not HTM) are produced.

Should the mills decide to market HTM instead of sugar, one source argues that they would incur the following savings (41, p.2): minimization of the labor required in the evaporation process, and elimination of the crystalization process, centrifugation, sugar warehousing, internal transport, warehousing labor and packaging. Sugar losses would decrease. Steam and electricity requirements would diminish, lowering energy costs. The costs of maintenance, repairs, and parts and materials inventories would decrease. Supervision and administration costs would fall. Sales costs would be eliminated inasmuch as local distilleries would contract directly for purchases. Given a good price for HTM, such savings should help the Corporation to reduce its losses from the milling operations.

In summary, many technical questions remain unanswered with respect to what would happen to milling and refining costs with energy cane. Some design change and investment might be necessary. Insufficient capacity could be a problem in some mills. Weather could impede the proposed eight month milling season. Cane tops might complicate sugar extraction. But production of only HTM would eliminate the latter difficulty. It also would eliminate the refining process and could lower costs.

4. Summary and conclusions

Over time the Puerto Rican sugar industry has become increasingly concentrated and unprofitable. Currently, the government's Sugar Corporation owns all the mills but no longer owns any land. Many factors underline the large losses the Corporation has incurred in recent years. It supports private farmers by running the mills, by offering *refacciones* (short term loans), and by offering extensive services including subsidized machinery, seeds, and irrigation inputs.

Energy cane differs from current sugarcane mainly in the management techniques utilized. The seedbed is more thoroughly prepared and is leveled. Energy cane uses twice as many seeds, substantially more irrigation, and over three times as much fertilizer as standard cane. In contrast to present practice energy cane avoids the use of herbicides and eliminates the need for most insecticides. Harvesting requires different machinery because of the high yields. Trash is harvested instead of burned. Finally, farmers may use a conservation strategy which reduces costs, but also diminishes yield.

The sorts of changes that energy cane might require in the mills themselves remain a matter for future research. Should HTM replace sugar production, then several stages in the milling process and all refining would be eliminated.

When the differences in inputs are considered, energy cane production would cost the government, in very rough figures, about $700,000 more per year than current sugar cane. However, assuming yields of 26 and 80 tons/acre for sugar and energy cane respectively, costs to the government per ton of cane would fall from $1.89/ton to $0.84/ton. The differences in milling costs remain uncertain for several reasons. From purely the cost side the impact on the government of adopting energy cane thus remains unclear. However, the potential for lower costs clearly exists. Given the larger revenues from higher yields as well as the multiproduct potential of energy cane, higher government revenues appear likely. Should revenues increase, the potential clearly exists for decreasing the losses of the Sugar Corporation or for showing a profit. However, the question of marketing and pricing of outputs, and therefore of revenues, lies outside the scope of this paper.

INDIRECT COSTS

The choice of any technology yields benefits and costs which directly and indirectly affect society, including its government. This division of the paper deals with the impact on the government of Puerto Rico of the environmental and other indirect effects of switching to energy cane technology from sugarcane as currently produced. The first section deals with the effects of changes in nutrient levels in rivers due in large part to the increase in fertilizer usage. The second examines the effects, most particularly with respect to human health, of decreasing pesticide usage. The third examines the indirect effects of producing high test molasses instead of sugar. An appendix explores possible other effects which the author could not examine in detail, such as the impacts on soil crumb structure and salinization.

1. Nutrient levels in water[1]

As outlined in the first part of this paper, compared to standard cane energy cane utilizes substantially larger amounts of fertilizer which may alter the environment. By affecting water hyacinth growth, for example, increased fertilization could affect flooding, wildlife and human health. These effects, in turn, could affect the government's tax receipts and expenditures. This section addresses these and other possible environmental affects and their potential impact on Puerto Rico's government.

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[1] Special thanks to Garcia and Tilly of CEER for providing the literature upon which this section is based.

a. Fertilizer usage

Table 3 summarizes the fertilizer usage at two of the four *centrales* in question over the last four years (other *centrales* did not provide detailed information). It is evident from the figures from La Plata that most likely they reflect a rule-of-thumb approach to cultivation practice in the area as opposed to actual sales figures. For instance, the field administrator of Central Mercedita told the author that, in 1982, 120 pounds of nitrogen, 30 of phosphorus, and 60 of potassium per *cuerda* were used over the 7,500 *cuerdas* the mill served. No discernible trend emerges from the figures for Roig. Of course, these figures represent only an estimate of fertilizer use in the area. Farmers can obtain additional fertilizer without going through the *central's refacción* system.

b. Transport[1]

Given that fertilizer use may be expected to increase, how much may nutrient levels in well and surface water be expected to change? The answer to this question depends upon the soil types in the area, types of fertilizers used, methods of application, and biochemical processes in the soils.

First, in the Plan the soils allocated for sugarcane tend to be rather nonporous. Although there are soils in the humid coastal valleys and on the south coast which are porous, the majority are not (60). Consequently, the likelihood that nutrients will leach through the soil and enrich well water appears low. This raises the probability that nitrogen (N) and phosphorous (P) may enter surface waters.

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[1] This section is based on (55) and previous sections of this paper unless otherwise noted.

Whether nutrients enter water systems through overland flow or through erosion depends upon several factors. In the case of overland flow such transport of nutrients is likely when nitrate fertilizers are applied on the surface of sloping lands. Nitrate fertilizers move with water because they are easily leached whereas ammonium fertilizers absorb on the soil. Phosphorous and potassium (K) also tend to absorb on soil particles. Therefore, nitrogen will move overland when it is in nitrate form whereas nitrogen in the form of ammonia, phosphorous and potassium moves on sediment.

Much of the transport mechanism for nutrients used in energy cane depends upon the type of fertilizers which would be used. However, generally nitrogen does not bind to the soil (60). With this in mind, the larger amount of fertilizers and irrigation indicate a large potential for overland transport of nitrogen, particularly inasmuch as 200 pounds of fertilizer will be applied on the surface along with increased amounts in the furrow. On the other hand, the flat seedbed should mitigate the flow to some degree.

It should be noted that energy cane takes up a greater amount of nutrients than sugarcane. According to Alexander, sugarcane typically shows a dry matter/applied nitrogen ratio of approximately 25 tons green whole cane/135 lbs. of nitrogen, or 0.19. Energy cane, on the other hand, has ratio of over 100 tons whole green cane/400 pounds of nitrogen. For instance, data from Table 2 of (3) show a ratio of 121.4 tons/400 lbs. of nitrogen for US-67-22-2, the preferred variety (detached trash is omitted from the figures). This gives energy cane a ratio of 0.30 compared to 0.19. Thus, although the nutrient composition of soil and plant are not available for a simple budget analysis of nutrients, one can say that a greater percentage of the applied nitrogen is taken up by energy cane than with sugarcane.

Similarly, the practice of burning sugarcane fields to remove trash leaves nutrients on the soil surface whereas energy cane harvests trash, reducing this nutrient input. The nitrogen from burned trash may or may not bind to the soil. Also, as with applied nitrogen, some may be lost to the atmosphere. So, it is not clear what the net difference may be between nutrient additions to the soil for the two canes due to trash burning.

Water also may leach nutrients from both dead and live plant tissues. The higher density of energy cane would increase the amount of nutrients entering surface water from this source.

In summary, because of the three-fold increase in applied nitrogen, half of which is surface-applied, it is likely that the overland flow of nutrients will increase with energy cane. However, the degree to which this occurs will be mitigated to a large or small degree by the flatter seedbed, harvest of trash, and greater uptake. The amount of phosphorus and potassium in the runoff probably will not increase much because they normally bind with the soil. The exact amount entering the water also depends upon the amount lost to the atmosphere.

Nutrients also enter water systems via erosion. When soil has a high organic content, nitrogen transport by erosion usually occurs for two reasons. First, organic particles tend to be lighter than the original soil and to remain in suspension. They typically contain 0.07 to 0.3 percent nitrogen.

Second, the silt and clay particles in soil erode more than the sand particles and contain more organics. Thus, the resulting sediment typically contains 50% more nutrients than the original soil with values five times higher sometimes occurring.

Although the nitrogen from fertilizers largely may move through overland transport, the phosphorus moves mainly through erosion because it absorbs on the soil and binds mainly to the finer particles.

The flatter energy cane seedbed should reduce erosion. However, the amount of nutrients in the sediment may decrease less than the erosion. Erosion control tends to reduce the transport of coarser, heavier particles more than that of lighter, smaller particles. Consequently, because nitrogen and phosphorus tend to be associated with light, fine particles, reducing sediment may not proportionately reduce nutrient transport.

Again, when one takes into account the increase in fertilizer application, probable decrease in erosion, decrease in trash burning, larger amounts of organic matter, and greater plant uptake, it is not clear what the net effect on erosion transport may be. It appears likely that at least some increase in transport should occur.

Once eroded materials enter streams and lakes they play an important role in nutrient cycling. Typically they release their nutrients slowly under aerobic conditions, acting more as a sink of nutrients than as a source. Water bodies typically lose nitrogen by denitrification in muds (14, p. 53). It is well-established that the recycling of phosphorus from sediments is small (29, pp. 20-21). Muds rapidly absorb phosphorus (14, p. 53). Under anaerobic conditions, however, phosphorus compounds (mainly ferrous) become highly soluble. Thus, should dissolved oxygen levels fall, as occurs with water hyacinth invasions, phosphorus would be released from the sediment, increasing the amount of nutrients available in the water (29, pp. 20-21). Then, to the degree that anaerobic bottom waters get mixed with more aerobic upper level waters more nutrients will be available to plants (See 29, p. 22). Finally, water hyacinths (to be discussed below) remove phosphorus in solution and disturb the phosphorus equilibrium between water and sediments, thereby causing more phosphorus to be released from the muds. Thus, should nutrient enrichment cease, hyacinth would help lower hydrosoil (sediment) phosphorus levels (13, p. 101).

In summary, the net effect on water nutrient levels from the growing of energy cane is difficult to determine. It would appear likely that nitrogen levels at least would increase somewhat. Phosphorus levels in sediment probably will increase at least to some degree.

c. Effect of possible increase in nutrients

As discussed above, the soil types in the areas under study most likely will prevent much leaching of nutrients into groundwater. Consequently, potential health effects from drinking nutrient-enriched well water should be negligible.

The paragraphs below deal with the effects of nutrients on rivers and streams. The area under consideration has very few lakes and no reservoirs.

Most of the effects discussed below deal with impacts on aquatic macrophytes, particularly water hyacinth (*Eichhornia crassipes*). However, the increased N & P levels in rivers could affect stream aquatic life in other ways by affecting algae populations, dissolved oxygen levels, and animal populations. Changes in stream conditions could affect ocean life. For instance, the export of N & P from agriculture to the nutrient-poor ocean waters surrounding Puerto Rico might improve fishing there (19). This could raise industry revenues and thereby raise tax revenues. However, this is a matter of debate.[1]

Before discussing the possible impacts of increased water hyacinth populations it would be wise first to consider whether increased nutrient levels would foster hyacinth growth. Unfortunately, the critical levels for hyacinth growth are unknown. Brezonik and Shannon's study of Florida lakes suggest that these lakes can assimilate more nutrients than those in Europe and the rest of the United States (cited in 29). They found that low values of the cation ratio, (Na + K/Mg + Ca), tended to indicate eutrophic conditions. Negrõn found the opposite in Puerto Rican lakes (29)[2]. She also discovered a great difference in inorganic nitrogen concentrations in the Puerto Rican lakes and rivers studied, concluding that NH_3 and NO_3 may play important roles as limiting factors in hyacinth growth (no data for rivers were given). Other sources refer to the limiting effect of both N & P (14, p. 52) and to the role of P as a limiting nutrient for aquatic angiosperms and macrophytes (20,38). Boyd found that hyacinths generally absorb N five to ten times faster than P, even though the latter is absorbed rapidly.

Brezonik and Shannon do show that as much as 0.12 g/m^3 (or mg/l) of total phosphorus and 0.86 g/m^3 of total nitrogen can be tolerated in Florida lakes without eutrophication becoming visible. Using this as a crude yardstick, Table 4 gives the mg/l concentrations found in

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[1] See below for more related discussion

[2] In comments on a draft of this paper, Tilly asserts that Negrõn incorrectly interpreted her results.

samples of Puerto Rican rivers in the sugarcane areas being studied (see Map 2 for sampling station locations). The figures give the minimum and maximum concentrations found for 1979-80, 1981-82 and the arithmetic mean (in parentheses). Water hyacinths exhibit luxury consumption of nutrients, particularly phosphorus (63, p. 366). Because the plant stores nutrients, concentrations below those limits may not prevent hyacinth growth. However, if both the average and maximum figures both fall below the limit, this would suggest that a river has a higher probability of being below the limit than if only the average were below. Two rivers appear to be in a low nutrient situation. The Río Grande de Añasco station, 1460, which is above the town of Añasco, appears to have been below the phosphorus level for the first year and above it in the second. However, the second year's data contain more observations. Río Guayanés above Yabucoa (station 0835) has nutrient averages below the limit but maximum levels above, with the exception of a maximum P level below the limit in the second year. Downstream at station 0865 all the average figures fall below the limits. The remainder of the rivers already appear to have average figures above the limits. Consequently, it appears that in a few cases additional nutrients could increase the probability of providing a minimum environment for hyacinth. In the other cases the environment would be enriched beyond the minimum.

Not only do we not know the critical limits for hyacinth, but neither do we know its response curve. It is well established that the plant responds to increased nutrients (see 22 for a relationship between the percent of nutrient in the plant tissues and the percent of nutrient in the water medium). Specimens in a rapid growth phase (younger plants or those with room to expand) exhibit mineral uptake rates per unit of dry matter increase that are faster than slower growing specimens (13, p. 98). Although hyacinths do not exhibit any correlation between total live plant biomass and any nutrient for flowing and non-flowing sites, Lugo et al. did find that they exhibit a linear correlation with an index comprised of the sum of iron, potassium, sodium, phosphorus, and nitrogen. They further postulate that the plants grow faster in high flow areas because more nutrients come into contact with the roots (26, pp. 416, 429 & 430). So, although nutrient levels affect the rate of growth of hyacinth, the critical levels and N & P response curves remain a matter for future study.

Thus, before the effect of energy cane on hyacinth production in rivers can be determined a better knowledge of existing nutrient levels in the rivers must be obtained, the transport mechanisms must be laid bare, and the responsiveness of hyacinth under these flow conditions must be established. The decomposition of hyacinth will further affect nutrient levels. To the extent that the decayed matter is assimilitated by phytoplankton or by sediments nutrients may build up. To the extent that live plants or decayed material are washed away fewer nutrients will build up in the riverine system and more nutrients will enter the ocean.

The degree to which nutrient levels change in the rivers should affect the animal and plant life there. Rho and Gunner showed that decomposing water milfoil changed the distribution and abundance of algae species (38). Similarly, one might expect other organisms, including fish, to be affected.

In a similar vein hyacinth's effect on dissolved oxygen levels in turn will exert an influence on animal life. Water hyacinth reduces oxygen in the water column. By shading the water it reduces the rate of production and rate of transfer of oxygen from the air into the water. Moreover, the large loads of organic matter it contributes oxidize in the mat or on the bottom. The matter on the bottom exerts such high oxygen demand that anaerobic conditions can exist below 15 meters in lakes, creating unfavorable conditions for desirable fish species such as bass (35, p. 101; 26, pp. 416 & 417). Similar effects should occur in rivers.

The interaction between increased nutrients and lower dissolved oxygen and the effect on wildlife needs further examination. If stream aquatic life is affected, probably ocean plant and animal life will be affected in turn. The changes in DO and nutrients should affect the ocean in either case. To the extent that commercially desirable fish are affected or that coral reefs important to commercial fishery (or tourism) are affected, then income will rise or fall, thereby affecting government tax receipts.

Some indication of the importance of fishing in the allocated sugarcane areas may be obtained from the following figures. According to CODREMAR, the total value of finfish and shellfish landed from shallow waters reached $4,298,580 in 1980, conservatively estimated. Of this amount about 14% came from fishing towns in the areas being studied. Four percent of the total came from Aguadilla alone (34).

Changes in sedimentation and nutrient levels could be expected to affect most directly the production of shallow water sealife. All the areas being studied, especially the west coast areas, contain endangered offshore coral reefs which are important for commercial fishing. To the extent that the use of energy cane improves or degrades the already deteriorating reef environment it should have some impact on commercial fishing.

Determining exactly what the dollar impact on the industry would be requires a sophisticated study. As fishing grounds deteriorate, for example, fishermen may shift to other areas, switch to fish having either a lower value or higher cost per unit catch (or both), and/or increase fishing effort. Moreover, prices, fish stocks, and regulations keep changing.[1] Once the study determines the producers' response to environmental change and its effect on profits, then it can proceed to examine the impact on the government.

Should the government decide that it needs to control the hyacinths without decreasing the upstream fertilizer input, then expenditures will rise. The cost of such clearing depends upon the geographical distributions of the infestations and the method used. Should the hyacinths be widespread, the cost of clearing could be very high. Mechanical harvesting on lakes tends to be impractical because of the expense and the often steep reservoir sides (16, p. 193). The expense, particularly for transportation, would appear to make harvesting impractical along most rivers. Typically, water weeds have been controlled worldwide with the use of herbicides, particularly 2,4-D. The latter is harmless to fish (16, p. 193). Other chemicals sometimes directly kill fish and other organisms (13, p. 95). The possibility that these herbicides

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[1] See Freeman III, A. Myrick. The Benefits of Environmental Improvement: Theory and Practice. Baltimore: Johns Hopkins, 1979, p. 242.

might affect downstream agriculture suggests they be used sparingly (16, p. 93). However, the wholesale killing of plants presents another problem. When large quantities of plants are destroyed, the nutrients therein quickly recycle. Decomposition then lowers the dissolved oxygen supply and threatens all aerobic organisms (13, p. 95; 35, p. 102). These effects might add to the environmental costs which the treatment was intended to avoid.

Water hyacinths may affect rivers in another way besides altering nutrient and dissolved oxygen levels. By affecting evapotranspiration rates hyacinth may affect the amount of water available for agricultural and industrial use in the affected areas. Studies disagree as to whether these plants increase or decrease evapotranspiration. According to Brezny, _et al_. evapotranspiration of hyacinths was 30-40% higher than free water surface evaporation under equivalent conditions, with significant positive correlations existing between daily maximum air temperature, daily average wind velocity, free water surface evaporation and evapotranspiration (15, p. 197). In a static water experiment Rogers and Davis found that water loss from containers with water hyacinth exceeded the loss from those containing only water by 5.3 times. It appeared that greater water loss occurred among the more rapidly growing plants. Water losses in a continuous flow experiment equaled 225 ml/-plant per day compared to 150-163 ml/plant per day for the static water experiments (44, pp. 424 & 427). Timmer and Weldom found evapotranspiration rates 3.7 times higher than open water (cited in 44). Lugo, _et al_. found that evapotranspiration was _lower_ than water surface evaporation during periods of slow growth (such as during drought) and higher during periods of rapid growth when water supply is abundant (25, pp.

194, 208-209). If the latter is correct, then the net effect of evapotranspiration in times of abundant water would depend upon how closely the water is budgeted. Should the evapotranspiration be sufficient to threaten existing water usages, then the government may be forced to increase expenditures on clearing hyacinth in order to avoid loss of economic output, as well as subsequent decreases in tax revenue (whether the extra expenditures would be warranted by the loss in taxes is another question). On the other hand, during periods of drought hyacinths could increase water availability by lowering water lost through evaporation. This could minimize loss of tax revenues through loss of economic output should water scarcity prove a problem. Thus, it is possible that hyacinth could serve a positive function. The studies on evapotranspiration conflict, however. Without knowing how much fertilizer would enter the rivers, how hyacinths would respond, and how much evapotranspiration would occur in a riverine system, it is difficult to predict what overall impact the plants would have. This would have to be related to present and projected water usage in the areas involved.

An increase in water hyacinths presents the further possibility of providing more habitat for the snails which transmit schistosomiasis (_S. mansoni_).[1] Water hyacinths and other water weeds provide good breeding grounds for these vectors. Of the sugarcane areas Humacao remains the only area with an endemic schistosomiasis problem (30, p. 13). Puerto Rico's snail control program was estimated to cost $66/m^3 of snail habitat treated in 1978. Jobin recommends chemotherapy as the cheapest methods of controlling the disease now in the endemic zone at a total

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[1] For the historical link between the spread of the disease and the construction of sugarcane irrigation systems in Puerto Rico, see (23)

cost of $1.6 million (24, p. 152). Determining the extra control cost due to snail habitat would require estimates of increased water hyacinth growth, increased snail growth, and increased chemotheraphy treatments required.

Finally, there is some evidence that floodprone river zones sometimes are the direct cause of large aquatic blooms in the mouths of rivers (29, p. 1). Increased hyacinth production could cause flooding which in turn could inflict agricultural and property losses. The latter could cost the government money in terms of direct losses, relief expenditures, and lost tax revenues.

d. Summary and conclusions

It appears likely, though not at all certain, that nutrient levels in Puerto Rico's streams and rivers would increase as a result of the use of energy cane. Groundwater probably would not be affected. The increased nutrient levels probably would increase the growth of water hyacinths. However, the extent of such an increase cannot be predicted because of the scarcity of scientific information. Because of the effects of increased nutrients, of possible hyacinth growth, and of lower dissolved oxygen level due to hyacinth blooms, water life should be affected in the streams and, possibly, in the ocean. The government could benefit should economically advantageous species increase. Fishing revenues could increase and thereby increase tax revenues. Because most fishermen tend to be poor and therefore, pay little in taxes, the impact would be small in either case. However, the opposite could occur. Hyacinths could affect the quantity of water available for use by changing the evapotranspiration rate. This could affect the local economy positively or negatively, with subsequent effects on government taxes and/or expenditures. They could increase habitats for the snails transmitting schistosomiasis and thereby increase disease control expenditures. The hyacinths occasionally can cause flooding. The main problem hindering estimates of dollar impacts on the government remains the lack of scientific studies and data.

2. Pesticide use and effects

The different techniques used in sugar and energy cane cultivation create different patterns of pesticide use. Sugarcane cultivation utilizes large amounts of pesticides whereas energy cane uses very little. A switch from sugar to energy cane would result in a much lower use of these chemicals on the island and, in turn, would decrease their concentration in the cane fields and in the environment in general. The detrimental effects to human health and wildlife resulting from occupational and indirect environmental exposures would also decrease.

a. Pesticide use

Due to its rapid growth, energy cane requires almost no pesticides (see above). It should not be assumed that pesticides will never have to be used in energy cane fields. However, the experience with experimental plots suggests that even if they are used, the amount of pesticides used in energy cane will be much lower than the amount being used in sugarcane.

Sugar cane growers use a large amount and a variety of pesticides. Detailed pesticide use data (Table 5) were obtained from sales figures for two sugar mills in the study area. The figures constitute only an estimate of pesticide usage in these areas since there are other sources from which a farmer may buy these chemicals. In 1982, the centrales under consideration sold a total of 170,335 units of herbicides and insecticides.[1] During that year, an average of 0.09 units of insecticides and 5.98 units of herbicides were applied per acre of sugar land.

However, it should be noted that the use of pesticides by sugarcane growers probably decreased in the period from 1978 to 1982. In the Humacao area pesticide use decreased almost 25% in 4 years while the area of cultivated land remained virtually unchanged. A closer look at the figures for La Plata reveal that, in all likelihood, the mill manager did not provide actual sales figures but only estimates based upon a per/acre rule of thumb for pesticide application (the same appears true for fertilizer use). Consequently, only the figures from Roig provide any reliable indication of pesticide use over time. The lack of growth in pesticide use may be due to the poor state of the Puerto Rican economy during this time period. A sugarcane grower hard-pressed by a poor economic situation will tend not to increase his use of these expensive chemicals and perhaps will use less. Since the lull in sales is probably due to economic reasons and not to a change in cultivation practices, it cannot be predicted that pesticide sales will continue to decline. If the economy improves, pesticide use might increase.

b. Effects of pesticide use

If a switch were made from sugar to energy cane cultivation, the decrease in pesticide use would lead to less exposure to pesticides in the work place and in the environment at large. Therefore, negative indirect effects of these chemicals would decrease.

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[1] This estimate derives from Table 4 and average applications per acre cited for the other centrales.

Detrimental effects depend largely on the toxicity of the pesticides. Diuron, Dalapon, and Ametryne are the most commonly used pesticides, representing 94.75% of total sales in 1982 for the _centrales_ polled. Being urea, organic acid, and triazine herbicides, respectively, all three possess low acute toxicity. They may cause growth depression and skin, eye and nose irritations. None is known to be a carcinogen or mutagen (27, pp. 305-401). In summary, these pesticides pose a moderate to low threat to human health. However, the large quantities used create the possibility of some damage.

In the case of accidental poisoning, for example, the effects of mixing and applying these chemicals to the crop may be very noticeable. On the other hand, persons working with pesticides, and the general population, could experience chronic effects that are hard to trace to low concentrations of pesticides without epidemiologic studies.

The rate of pesticide-related health problems in the sugarcane industry in Puerto Rico is not known. However, a review of the complaints filed by sugarcane workers with the Puerto Rico Department of Agriculture's occupational health program showed no pesticide-related poisonings. Two factors may explain this lack of poisonings: either none occurred or they occurred and were not attributed to pesticides. The latter may occur in cases of poisonings having non-specific symptoms.

The applicator's knowledge about pesticides represents a very important factor in determining the occupational and environmental damage pesticides cause. Villares (61) found that in 1967 agricultural applicators and farm owners in the Barranquitas area (a non-sugarcane area) had completed less years of school than the general population of the island. They also began applying pesticides at an early age, as early as 10 years. Both factors suggest that at that time applicators lacked sufficient knowledge about safe handling of pesticides and therefore might have used them incorrectly. Villare's study demonstrated that a greater amount of pesticides was applied to the land than was recommended by the U.S.D.A. This situation should have improved since due to a program implemented by the Commonwealth's Department of Agriculture. The agency requires that all pesticide applicators obtain a license by passing tests dealing with the correct formulation, application, and disposal of pesticides. The impact of this program on the handling of pesticides on the island is not known.

Besides poisoning workers, pesticides also can contaminate the environment. This can cause chronic illnesses in persons exposed to trace quantities of these chemicals and sickness and death of wildlife. The degree to which pesticides translocate from the site of application to the environment, the persistence in the environment of these chemicals, and their toxicity determine the extent of environmental damage.

In the case of Diuron, Dalapon, and Ametryne transport is likely to be both via soil and water. Diuron and Ametryne do not dissolve well in water and they tend to adsorb to soil particles. Their predominant transport mode, therefore, will be soil erosion. On the other hand, Dalapon dissolves well in water. It will tend to be transported in solution by run-off. Therefore, the best transport indicators consist of field erosion for Diuron and Ametryne and water movement through a field is the best indicator of pesticide transport regardless of solubility because the volumes of water used are so much greater than the erosion that occurs (62).

Immediately following their application to a field, the pesticides begin to be degraded by bacteria, fungi, photooxidation, soil enzymes, and catalytic agents in the soil (27). A pesticide that can withstand these factors is said to be persistent. The longer a pesticide persists in the environment, the longer it can cause damage. Dalapon is non-persistent. No data are available for the other two herbicides (62).

The interaction of transport, persistence and toxicity determines the relative environmental damage that a pesticide can cause. The pesticides used in sugarcane have low acute toxicities. Dalapon, at least, does not persist. Therefore, no massive environmental damage should be expected from these pesticides under normal conditions. However, Willis and McDowell (62) suggest that pesticide loss happens in pulses. The greatest amount of pesticide loss should occur when heavy rainfall (and perhaps irrigation) follow shortly after application of the pesticide. Otherwise, less than 5% of the pesticides applied will be lost (62).

In his study of pesticide use in Barranquitas Villares (61) found that, although pesticides were being used at a rate greater than that recommended by USDA, pesticide concentrations in river sediment and several species of fish and shrimp were below the levels of detection. The only exception was Diuron which was detected at a concentration of 0.85 ppm in river sediment from the Central Azucarera Aguirre and at 0.94 ppm in the tissue of blue gill fish. U.S. Geological Survey data for water quality stations near present sugarcane fields also show concentrations below the detection limits for several pesticides (Table 6). Diazinon, Lindane and Malathion constitute the main exceptions. They show lower than 1 ppb.

Several hypotheses may explain the low concentration of pesticides in streams near sugarcane fields. Possibly, no pesticides have been detected simply because none have been transported. Pesticides may be present in streams but may be adsorbed to soil particles and undetectable (this does not appear to be the case for Lindane and Malathion in Table 2). It also is possible that high concentrations of pesticides may be found only in sporadic intervals when heavy rainfall occurs shortly after application of pesticides. There is not enough data to distinguish between these hypotheses.

By far the most important factor in comparing the environmental impact of sugar versus energy cane pesticide use is the large quantity of these chemicals used in sugarcane. If the conservative estimate by Willis and McDowell is used that 1% of all soluble and 0.5% of all insoluble and soil-incorporated pesticides reach lotic systems, then approximately 468 units of Dalapon and 573 units of Diuron and Ametryne reached streams in the study area in 1982. A switch to energy cane would prevent this exposure.

Should these chemicals affect fishing in the ocean, then a switch to energy cane would offer the possibility of improved fishing revenues and taxes. As discussed in the section on fertilizers, this effect on the government probably will be small. To the extent that worker health complaints caused by pesticide poisoning (but attributed to other factors) decrease, then government-borne medical expenses will decline. Similarly, should pesticide use affect drinking water quality, a switch to energy cane would decrease the number of related illnesses for which the government might bear some share in the cost of treatment. The likelihood of these occurrences and the magnitude of cost savings incurred cannot be estimated without more research (see recommendations section).

c. Summary and conclusions

Pesticide use has remained stable or declined in sugarcane areas, mainly as a result of the recession. Should growers switch to energy cane, pesticide use would drop dramatically. The three most commonly used pesticides in sugarcane cultivation. (Diuron, Dalapon, and Ametryne) all possess low toxicity. Diuron and Ametryne tend to be transported through soil erosion whereas Dalapon tends to move via water transport. Dalapon is non-persistent. No data on persistence is available for the others. Although few pesticides have been found in stream waters near cane fields, the reasons for this remain unclear. Similarly, the reason for the lack of reported pesticide poisonings among cane workers is uncertain. There is not likely to be massive environmental damage from present cane cultivation. The switch to energy cane will reduce the present level of damage substantially. Whether this will have much impact on tax revenues and governmentally-borne medical expenses or not requires further research.

3. High Test Molasses and Rum

As discussed previously, the energy cane approach includes the production of high test molasses (HTM) in lieu of sugar, except when sufficiently high sugar prices warrant some sugar production. The HTM would serve as the raw material for the Puerto Rican rum industry which currently uses blackstrap molasses (BSM). Substituting HTM for BSM could have several indirect effects on the Puerto Rican government and society. This section discusses these effects by: 1) discussing the role of externalities, 2) discussing the environmental and economic impacts of using HTM instead of BSM, 3) reviewing the impact on rum production and on government revenues, 4) investigating the effect on the vulnerability of the Puerto Rican rum industry, and 5) summarizing the overall impact of the above factors.

a. Externalities and optimum output

Several sections utilize the concept of "externalities." Economists define (nonpecuniary) externalities, or spillover effects, to be costs or benefits of an activity which affect third parties but which do not pass through the price system. When a chemical company dumps waste into a river and people downstream become ill as a result, an externality exists in the production of the chemical. People downstream bear a cost of the production of the chemical which does not affect its price. Similarly, a beekeeper who markets honey provides free pollination services to a neighboring orchardman. The orchardman reaps a benefit from honey production which is not reflected in the price of honey. In neither example does the chemical company or beekeeper take into the account the external cost or benefit of his activity when deciding how much to produce.

Economists generally use demand and supply graphs to illustrate the impacts of externalities. They demonstrate that negative externalities, such as the dumping of chemicals into a stream, raise the costs to society of producing chemicals above the costs to the producer. Thus, firms produce too much chemicals at too low a price. When positive externalities exist, as in the bee example, firms produce insufficient honey because the market price does not capture all the benefits to society of honey production. The presence of externalities, therefore, affects the amounts of goods and services which, according to economic analysis, should be produced to maximize society's welfare.

In the case of the rum industry, an industry characterized by a few interdependent firms which are sufficiently large to set their prices where they wish, the demand/supply analysis proves of little help. Consequently, in the paragraphs which follow little reference will be made to the impact of HTM on the socially optimum amounts of rum which should be made.

b. Environmental impact of HTM

Scholars agree that distillery slops (mosto) can create several local water pollution problems. Bacardí's Cataño distillery alone daily dumps into the ocean 550,000 gallons of slops, the equivalent of the sewage of a city of 825,000 people (BOD basis). Omitting the Serrallés distillery which pour its slops on its cane fields, the Puerto Rican rum industry discharges 750,000 gallons per day or 225 million gallons yearly into coastal water (50, pp. 5&6; 57).

Slops from molasses distilleries typically are more difficult to treat than other slops. They possess a high, biodegradable dissolved solids content of around 35,000 mg/l (BOD_5). Slops have high concentrations of potassium, calcium chloride, and sulphate ions long with a low pH. Finally, they enter the ocean while still hot (51, p. 258).

The question of the effect of slops on aquatic ecosystems remains relatively unstudied. Although mosto contains very low levels of toxic materials identified by the Clean Water Act, the BOD is considered the cause of major damage to marine organisms (32, pp. 18 & 20). Verma et al. showed in 1976 that raw stillage has a dramatic effect on fish (cited in 51). In CEER's study of the Arecibo area both biological field studies and laboratory bioassays showed that mosto has an adverse effect on low intertidal organisms though the effect was not noticeable at very low concentrations. Some organisms of fundamental importance to the ecosystem paticularly were severely affected. In addition, by affecting various organisms to different degrees the presence of slops may have restructured marine communities (21, p. 58). Chemical analyses of seawater indicated that the discharge's impact could be observed several kilometers downstream from the outfall. Abbreviated studies at the Bacardī site in Palo Seco suggested a greater impact there than at Arecibo. Moreover, the erratic water currents at Palo Seco transport effluent to other regions, exposing them to harmful impacts. The report calls for a separate study of the Palo Seco area because the marine environments are so dissimilar that the results for Arecibo may not be applicable to Palo Seco.[1]

In response to these and other findings the EPA has required that all rum plants in Puerto Rico install waste treatment facilities by 1983 to treat slops discharged into coastal waters. The Reagan administration has given some indication that it might relax this requirement, raising doubts whether or not firms will have to incur these costs. Bacardī, however, already has built its anaerobic digestor. The use of HTM instead of BSM in rum production would have several environmental effects. This paper will assume that all HTM not needed for rum production will be exported instead of converted into fuel alcohol, for instance. With either HTM or BSM the amount of stillage is about the same because all molasses are diluted to similar concentrations.[2] Thus,

[1]Bacardī no longer discharges into Boca Chica bay in front of Palo Seco. It now mixes and dilutes its discharge with a large volume of municipal waste in a 10' diameter, deep ocean out fall which discharges 1.7 miles from the ocean (57).

[2]This ratio can be lowered up to 50% by various changes in rum technology; e.g., continuous fermentation (50, p. 17).

one gallon of rum yields 6.5 gallons of slops in either case. However, data shows that slops from HTM contain approximately 50% less BOD than that from BSM (11, p. 5). Consequently, if firms are allowed to dump slops directly into the ocean, HTM will cause substantially less environmental impact for a given amount of rum production than BSM. If the waste is treated first, the final effluent may or may not have less BOD, depending upon the process used. Treatment costs would be lower (see below).

The impact that the discharge of slops has on the economy of the island requires further study. The economic impact of the environmental degradation from slops around Arecibo appears to be slight (the question of the impact of waste disposal on the cost of producing rum will be discussed later). According to the CEER report, few tourists use the beaches because of strong wave action and rocky shores. Residents of Barrio Obrero (west of the distillery) may bear some costs, if only aesthetic, from having the beach polluted. Other beaches either are inaccessible or are poorly developed and poorly visited. With the exception of occasional surfers no one practices water sports in the area. Fishing occurs basically only in one community, Jarealitos, east of Arecibo. The industry there produces one percent of the total fish caught in Puerto Rico (p.116). If their catch is affected by the pollution west of their town, then this may be the main economic impact of the distillery's pollution. Less is known about the situation in Cataño and about the economic significance of discharges there.[1]

[1] The whole question of valuing the costs to society from pollution does not end with production impacts. People value aesthetics, the existence of wildlife, and so forth. These values also need to be accounted for. Ecosystems provide life support sevices for humans. How and whether these services should be valued is the subject of debate. Suffice it to say that, even in Arecibo, there is a cost to society from the pollution. Valuing it, however, involves tricky conceptual and empirical problems.

Should the EPA allow the dumping of raw stillage, the external cost will be less with HTM. To the extent that the lower external costs translates into greater earnings for the tourism of fishing industries, for example, then the government benefits from the use of HTM via increased tax receipts. Should the EPA continue to require waste treatment, the use of HTM could decrease environmental damage. Bacardī's anaerobic digestor should perform more efficiently, thereby lowering the BOD of its effluents (57). The impact on Puerto Rico Distillers' effluent remain unclear due to the uncertainty as to the system they might use. Any improvement in BOD levels could affect economic activity and taxes. The tracing of these effects requires further research.

c. Effect of HTM on rum production

Aside from possibly affecting the environmental impact from rum production, the use of HTM may affect rum production and sales, indirectly providing benefits to the Puerto Rican government. In 1979-80 the rum industry contributed $224.9 million to the Commonwealth's treasury. The following year that figure grew to $271.1 million of which $242.5 million came from the return of federal excise taxes and $28.6 million came from local taxes (43, p. 1). These figures constitute about 1/7 of the Puerto Rican government's General Fund recurring revenues (49, p. 1). Therefore, anything which serves to increase sales of Puerto Rican rum has an external benefit associated with it: it raises additional revenues for the government from rebated federal taxes.[1]

The use of HTM to produce rum should affect production costs in several ways. First, the basic costs of obtaining molasses differ. For

[1] Thanks to Lewis Smith for pointing out that this relationship takes the form of an externality.

instance, the cost for storage of molasses may increase. Although less molasses is required with HTM, George Samuels points out that since 1972 the Puerto Rican rum industry has imported BSM using a specific pattern of imports from various destinations to provide a steady supply and to minimize storage. With domestic production of HTM storage would have to increase to accomodate domestic HTM for the off season. Should the grinding season be lengthened to eight months, then only four months of storage would be needed instead of eight (49, p. 3).[1] Transportation costs of molasses would be less (17). Finally, the price of HTM will be higher than that of BSM.[2]

HTM affects the actual production of distillates in several ways. First, because HTM is cleaner than BSM, it requires less pretreatment costs before distillation can proceed (12). HTM yields more alcohol and makes yeast recycling more possible (12, 42). Moreover, all sources agree that it enables a much higher fermentation efficiency (much more sugar can be converted into alcohol). With HTM there is less pass through (17). According to one source, fewer distillation columns and, therefore, less labor are needed. Or, with the same equipment more can be produced in a fixed time period (98). Another source states that the number of columns and related labor will be the same because the beer to be distilled contains the same amount of alcohol regardless of the molasses used (57). The distillation process requires less energy (17; 51, p. 258). Finally, fewer incrustations occurs in the distillation columns, resulting in fewer work stoppages for cleaning (12).

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[1] For discussion of the feasibility of an 8 month season see Section 3b Direct costs.

[2] The question of pricing lies beyond the scope of this paper. It appears that the rum industry would be willing to pay current sugar prices for the extra sugar obtained from HTM (17).

Once the distillate emerges HTM use affects storage costs also. Because HTM distillates are of higher quality than those from BSM, they age in half the time. Commercial experience shows that in two years one obtains a rum as good or better than that obtained in four years with BSM. Therefore, the firm needs fewer barrels and less storage space. Typically, in the first 2-3 years of storage firms lose 15-20% of stored rum per year due to evaporation. Although some evaporation is necessary to remove undesirable volatile elements, the above rate of loss is unnecessary. The reduced aging time reduces these losses. In addition, distillers have less money tied up in stored rum. With expensive storage and high interest rates the reduction in aging time appears to be very beneficial (40, p. 13; [illegible]).

Finally, HTM use affects treatment costs. Some disagreement exists as to how costs are affected. Some believe that HTM leads to lower treatment costs (12, 42). Mosto from HTM distillation contains half the BOD of BSM mosto, therefore requiring less treatment. Retention time in the digestor decreases, enabling greater flow.[1] Thus, a firm either can use a smaller treatment plant or experience greater efficiency (42). However, Manuel [illegible] del Valle and Michael Szendrey of Bacardi point out that there is no change in treatment costs because the same volume of wastewater must be treated (pumping being the major cost). Although operating costs do not change, capital costs decrease. They point out that without a secure source of HTM a large digestor would be necessary to accomodate BSM slops should they need to switch (17, 57). Yet, if energy cane can provide the industry with a secure

[1] The Puerto Rican rum industry is more inclined to use mosto to generate gas than to use it for other purposes (50, p. 22). This implies the use of an anaerobic digestor, possibly coupled with an aerobic process.

HTM source, then smaller digestor will suffice. The EPA estimates that price increases of 2-8% can maintain profit levels when these treatment plants are built (32, p. 82). Energy cane would lessen this upward pressure on prices by lowering capital costs. HTM does have a disadvantage: it decreases the amount of recoverable energy from waste treatment. Thus, whereas Bacardi's second reactor might make it possible to replace most of its imported fuel with methane, the use of HTM might decrease methane production up to 50% (17; 56, p. 31; 57).

Overall the net impact of HTM on the costs of rum production remains unclear. The result depends partly on the prices of HTM and energy (fuel oil). It does appear likely that costs will fall at least some.

The impact of HTM on rum does not end with any possible effect on production costs, however. This change in input also affects the quality of the product. Because the input is higher in quality, the distillate has a cleaner aroma. BSM distillates have an odor (tufo) that requires aging to remove. The HTM distillate possesses a smoother, less bitter taste because, unlike BSM, HTM contains no burned matter. After aging HTM distillates for two years the resulting rum resembles BSM rum aged 4-5 years but possesses superior quality (40-42).[1]

The overall impact of the switch to HTM is difficult to predict. On the supply side firms should find their costs reduced somewhat. Accordingly, they could reduce price and increase output. If firms were to react this way, the Puerto Rican government would gain increased tax

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[1] This may be confirmed by Eng. Luīs Alberto Chamorro, General Manager of Compañía Licorera de Nicaragua, Chichigalpa, Nicaragua. This company has used HTM for rum production for a long time.

revenues from increased sales of rum. Extra profits would provide the government extra revenue from corporate income taxes. However, should the industry maintain price at current levels their profit would increase due to decreased costs. The main government benefit then would come from increased corporate income tax receipts. Generally, oligopolistic industries such as the rum industry tend to exhibit constant price and output in the face of changing costs. Given the impact of various federal regulations on the costs of the Puerto Rican industry most likely it will tend to hold price and sales constant and increase its profit margin.

On the demand side it would appear at first glance that the demand for Puerto Rican rums would increase as the quality improved from use of HTM. But, consumers tend to view product changes with suspicion. Even improvements can cause consumers to stop buying liquor because the product is not that with which they are accustomed. Consequently, distillers blend improvements into their product so that it changes gradually. With HTM under these conditions present consumers may not perceive any reason to buy more Puerto Rican rum. Non-rum drinkers or drinkers of other unchanged rums might switch to these brands when they try the improved versions. However, other rum manufacturers probably will copy Puerto Ricans if they perceive any lost sales. To the extent that demand does increase distillers can increase sales and/or increase prices. The government then benefits from increased excise tax receipts and/or income tax receipts. However, to the extent that consumers do not notice any quality increase prices and/or sales will not increase. This possibility appears most likely.

To estimate the actual pecuniary impact on the government requires dollar estimates of the environmental impact on the economy. However, this requires further studies not only of the ecological impact of mosto but of the degree to which these damages would decrease as BOD and toxic effluents decline. The effect of these impacts on economic activity requires further investigation.

In addition to further scientific/economic studies on mosto pilot runs with maintenance of detailed cost data need performing. The direction of many effects appears clear but the magnitude does not. One crucial question consists of the net change in energy utilization when HTM decreases energy used in the production of distillates but also decreases the availability of methane. As oil prices vary this factor becomes more and less important.

To predict how firms will react to changes in cost and quantity unfortunately may involve no more than educated hunches. Therefore, despite better scientific and economic studies the final estimate of the impact on the government of HTM use will depend, in part, on intuition.

d. Effect of HTM on rum industry vulnerability

Both because the rum industry largely imports its BSM and because the Caribbean Basin Initiative has removed tariffs on Caribbean rum, many have expressed fears for the Puerto Rican industry's future. Of course, to the extent that the industry is endangered so are the revenues of the government. Moreover, several observers point to projections showing U.S. sales of P.R. rum equal to 21.5 million cases in 1985 and 41.0 million in 1990 (43, p. 6). If the Puerto Rican rum industry falters, the government stand to lose even more. The following paragraphs discuss the validity of these fears and the role HTM may play in assuaging them.

Many observers have expressed concern over the fact that Puerto Rico has been importing ever greater proportions of its BSM since it started importing in 1972. In 1980 the industry imported about 87% of the molasses it used (50, p. 1). In 1982 the industry imported 33,-731,426 gallons of molasses, of which slightly over 21 million came from the Dominican Republic (43, p. 9). Projections indicate that 75 million gallons will be required in 1985 (50, p. 3). The concerns over these imports appear to take two basic forms: concern over the ability to use the "Puerto Rican Rum" label and over the availability/price of imported molasses.

Several observers have mentioned the possibility of rum producers requiring that rums stating that they are from a particular place must use only inputs from that locale. Such a definition would preclude the use of the "Puerto Rican Rum" designation because P.R. largely imports all of its molasses. Some consider this crucial because they state that, by a combination of strict quality control and publicity, people have come to know that Puerto Rican rums are quality rums. The label, therefore, serves as an assurance of quality. These observers point out that the question of local inputs has arisen several times in international congresses and that such a definition could arise. Foreign producers then could use such a definition to break P.R.'s hold on 86% of the U.S. market.

Yet, most recognize that no organization currently exists which could make such a definition stick. Moreover, both César Molina of Puerto Rico Distillers and Manuel Luis del Valle of Bacardí agree that consumers tend to buy brand names, not "Puerto Rican"; ie., if one removed the "Puerto Rican Rum" tag from Bacardí, it still would sell well (17, 33). Del Valle expresses fear more that people will think all Puerto Rican rums are the same because of the label rather than that the label will have to be removed. One disadvantage of losing the label would be the potential loss of the government's Puerto Rican Rum Group's advertising for all island rums. Whether the government would continue advertising without the label remains a question. Del Valle also points out that foreign producers could attempt an advertising campaign stressing the lack of local molasses in P.R. rum. However, he feels they will not take the risk of an ad war (17). Overall, the potential loss of the label does not appear either particularly likely or damaging.

The rum industry could, however, encounter problems from another quarter: the price and availability of imported rum. As more and more Caribbean distillers attempt to sell rum to the growing U.S. market, the price of molasses could rise. The substitution of ethyl alcohol from cane juice for fuel oil in many countries will reinforce the trend (43, p. 6). However, this trend should affect all distillers in the Caribbean and not work particularly against Puerto Rico unless less molasses actually becomes available for importation. Should most cane production go into fuel ethanol and foreign rum production the island may have difficulties obtaining secure supplies of molasses.

An oft mentioned aspect of this problem consists of a potential molasses cartel refusing to sell to Puerto Rico (see 10, 28). Such a move could destroy the industry. This does worry del Valle and Richard Roberts of Puerto Rico Distillers. However, del Valle rightly points out that a cartel which raised prices would run the risk of farmers substituting BSM for other feeds. Corn prices would have to stay high for the cartel to last long. Also, this writer believes that there probably are too many producers, and too many potential producers which easily could enter the market, for such a cartel to endure. In addition the Caribbean Basin legislation passed by Congress permits the President to reinstate tariffs on foreign rums should such action be taken (17; 43, p. 7). Consequently, the threat from a cartel appears slight over the long-run.

Planting 40,000 acres of energy cane would provide some measure of security to Puerto Rico in the face of the above possibilities. At 80 tons/acre yield this acreage would yield 56.3 million gallons of HTM, the equivalent of 84.5 million gallons of BSM. This would supply about 112% of the industry's HTM needs in 1985, and 93% in 1988, assuming a 5% yearly growth in rum production (49, Tables 3 & 4). By providing a secure local source of molasses the rum industry could be assured of its availability. It could not be assured of inexpensive HTM in the face of rising prices inasmuch as local HTM producers always could sell on the international market. To the extent that the above mentioned problems should threaten the government's rum revenues, the planting of 40,000 acres of energy cane would lower the risk substantially.

One cannot end a discussion of the current Puerto Rican rum situation without some mention of the impact of the newly passed Caribbean Basin Initiative (CBI). The act removes tariffs on Caribbean rum imported to the U.S. This could lead to retail prices up to 40c/bottle lower on competing rums (28). Several Puerto Rican rum spokesmen have expressed concern over this development. Felix Serrallés notes that competitors do not have Social Security, OSHA, and other federal regulations which raise their costs. In his opinion the tariff helped equalize costs somewhat (28). Competitors can ship in bond whereas island rums cannot (17). Others have expressed concern that bad rums will invade the market and give the industry a bad image. This would require Puerto Rican to advertise to offset the impact (17, 28). One observer feels that local sales might decrease some (42). But overall most agree that the legislation probably will have little impact on the industry. Particularly, the strong advertising program which has been in place for years along with good distribution channels should keep the island competitive (17, 42). The CBI may hold one Trojan horse for the Puerto Rican government, however. By rebating <u>all</u> federal excise taxes on rum to the commonwealth and the Virgin Islands these two governments will become used to a higher level of revenues. If the expanded rebate program terminates along with the trade preferences in twelve years, these governments will experience a rather sudden decline in revenue at that time.

The use of HTM in this context appears to have two possible impacts. First, by lowering costs the use of HTM may allow the rum industry to lower prices, somewhat counteracting the removal of tariffs. Second, the higher quality of the rum should enable P.R. to maintain its reputation of superior quality in the face of greater competition.

e. <u>Summary and conclusions</u>

The large volume of distillery wastes generated by the rum industry and the high BOD of these wastes significantly affect intertidal organisms and, possibly, fish. With the advent of EPA - mandated waste treatment the environmental impact should decrease. Because HTM slops contain fifty percent less BOD, the dumping of raw HTM slops into the ocean should have a smaller impact per unit of production that that of BSM slops. The same probably holds true under waste treatment regulations. The extent of reduction remains a question for further study.

The economic impact of rum slops in the Arecibo area appears slight whereas the impact in the area around the Bacardí site may be greater. The latter requires further study.

The most important effect of HTM may revolve around any potential impact on the rum industry's sales and/or profitability. Currently, about 1/7 of the Puerto Rican government's annual revenue comes from local taxes and rebated federal excise taxes on rum. HTM may reduce costs of production somewhat, as well as improve the quality of the product. Firms could reduce price and increase sales, thereby increasing government revenues. More likely, the rum industry would increase its profit margin by maintaining the same level of prices.

Predicting the overall impact on government revenues requires more scientific studies on ecological impact and how this relates to economic activity. A large pilot run of rum production using HTM is necessary to establish the various savings and cost increases HTM would bring. But then, predicting the behavior of the rum industry given this information may amount to an educated guess. Therefore, firm predictions of the impact on government revenues may be impossible.

Similarly, the impact of HTM on the vulnerability of the rum industry hinges on one's assessment of the importance of brand name recognition versus the "Puerto Rican Rum" designation, the potential significance of molasses cartels and molasses availability. and the impact of the Caribbean Basin Initiative. In this author's opinion the use of molasses for expanded foreign rum and fuel production may prove the greatest threat to the island's rum industry by making molasses supply insecure. Planting 40,000 acres of energy cane would provide substantial insurance against supply unavailability and other possible threats due to the lack of local molasses.

RECOMMENDATIONS

Direct Cost

1. A full-scale milling of energy cane needs to be performed to determine the effects of the cane on the milling processes and on costs.
2. The role of the weather in an eight-month grinding season requires further investigation.
3. The degree to which the mills would be operating up to capacity needs examination to determine what would happen to unit costs.
4. The extent to which the grinding of energy cane makes sugar production more difficult should high sugar prices warrant one or two strikes should be investigated further.
5. A thorough study of cost savings to the milling industry from producing only HTM and no sugar should be undertaken. One might ask whether such savings would more than exceed the net returns from maintaining the capacity of making sugar occasionally when prices permit. In the latter case sugar prices would have to be sufficiently high to warrant maintenance costs over a long period of time, the lost revenue from not selling unused equipment, and the operating costs of brown sugar production and sugar refining.
6. Further research on more efficient methods of irrigation of energy cane could lead to substantial saving to the government should the technology be implemented.
7. Research should examine whether current plants with minor modifications would be sufficient in any feasible energy cane scenario. Or, are investments in high pressure boilers necessary, for instance?

8. The growing of Saccharum species on marginal land needs to investigated further with respect to its economic feasibility.

9. More attention needs to be given to the integration of short-rotation crops into mill operations.

Nutrients in rivers

1. The most likely mix of fertilizers which farmers would use needs to be determined. Environmental problems could be minimized either by providing the components of the fertilizer separately or by mixing them particularly for energy cane growers. Such measures would minimize excessive applications of phosphorus and potassium by farmers attempting to increase nitrogen applications.

2. The type of transport of fertilizers which occurs will depend upon the form of fertilizers used. For instance, should nitrate fertilizers or ammonium fertilizers be used? What differing impacts would these fertilizers then produce downstream?

3. The data on the nutrient budget of energy cane need to be analyzed, permitting a better estimate of how nutrients will enter rivers.

4. A comparison of nutrients entering the water under conditions of burning fields and not burning fields needs performing. So does a comparison between leaching of nutrients from organic matter for energy and sugarcane.

5. Estimates of erosion need to be made for energy cane and current sugarcane. Then the impact of changes in sedimentation rates on nutrient transport should be examined.

6. Once the modes of transport and quantities of nutrients involved have been established, the cycling of these nutrients in the rivers in question requires examination.

7. The critical nutrient levels and response curve of water hyacinth must be established with respect to the stream flow conditions of the rivers in question.

8. Further research is needed on how hyacinth growth affects stream nutrient levels and dissolved oxygen levels.

9. How will the above factors combine to affect stream and ocean flora and fauna, particularly those of economic value?

10. Once the above effects have been determined, fishing behavior needs to be modeled to determine how fishing revenues will be affected by these changes.

11. The effect of water hyacinths on evapotranspiration rates needs to be determined more clearly. Then, the impact of water hyacinth growth on Puerto Rican rivers and water availability for economic purposes can be examined.

12. The potential for spreading schistosomiasis vectors as a result of increased habitat needs to be examined carefully.

13. The impact of hyacinth on floodprone areas needs further research.

Pesticides

1. Studies on the occupational health of sugarcane workers with respect to pesticide-related illness should be performed.

2. Epidemiologic studies are necessary to determine any impacts of low concentrations of pesticides from sugarcane cultivation.

3. To determine the presence of pesticides in stream water more frequent water quality sampling is needed. Samples should be taken right after major storms and irrigation and after pesticide applications. Sediment should be tested for presence of pesticides. More well sampling is needed.

4. Diuron and Ametryne need to be tested for their persistence in the environment.

5. More work needs to be done on the effects of these chemicals on wildlife, particularly on economically important aquatic fauna.

HTM and Rum

1. The environmental impact of slops from Bacardi deserves further study.

2. The impact on economic activity from environmental degradation due to rum slops from Bacardi requires study. Only then can the impact of slops discharges on the government be assessed.

3. Should the EPA regulations stick, the effect of HTM on slops content, and the subsequent degree of environmental impact, need to be assessed.

4. A large production run of rum using HTM needs to be performed to assess the various impacts on molasses storage costs, production costs, treatment costs, energy costs, and aging/warehousing costs.

5. The possibility of increased shortages of molasses due to increasing demand for molasses worldwide needs to be investigated further.

TABLE 1

Government Supports to the Sugar Cane Industry

Commonwealth	Federal
Refacción system	Price support
Transportation to New York	
Subsidized machinery services	
Subsidized seed prices	
Labor subsidy	
Loan and price incentives on machinery purchase	
Subsidized irrigation in some areas	
Operating sugar mills	

TABLE 2

COST TO ELA GOVERNMENT
OF 40,000 ACRES OF SUGAR
AND ENERGY CANE

Item[1]	Sugar cane	Energy cane	Net Change
Seed	$ 300,000	$ 600,000	+ $ 300,000
Subsoiling	0	304,000	+ 304,000
Water	1,512,000	1,512,000	0
Labor	151,000	242,000	+ 91,000
Total	$1,963,000	$2,658,000	+ $ 695,000

[1]Items are listed only when a difference is expected

TABLE 3

Fertilizer Use at Centrales Roig and La Plata 1978-79 to 1982-83 (in pound/cuerda)

Year	Roig [1]	La Plata [2]
1978 - 1979	502	NA
1979 - 1980	637	800
1980 - 1981	523	800
1981 - 1982	616	800
1982 - 1983	542	800

Source: Personal correspondence with mill managers

[1] Fertilizer mix varies from year to year

[2] 5-15-10

TABLE 4

WATER QUALITY IN RIVERS IN SUGARCANE AREAS,

1979-80 and 1981-81+

Location (water quality station number)	Total N (mg/l)		Total P (mg/l)	
	1970-80	1980-81	1979-80	1981-82
Río Culebrinas near Aguada (1491)[1]	.01-2.3 (1.8)	.79-2.1 (1.3)	.06-1.2 (.25)	.08-1.4 (.34)
Río Grande de Añasco near Añasco				
(1461)[2]	.51-1.6 (1.1)	NA	.06-1.4 (.09)	NA
(1460)[3]	.16-1.0 (.8)	.32-2.1 (1.1)	.02-.05 (.04)	.03-.63 (.15)
Río Guanajibo at Hwy. 119 at San Germán (13199)[4]	.19-1.4 (.7)	NA	.03-.15 (0.12)	NA
Río Guanajibo near San Germán (1336)[5]	1.1-3.3 (1.9)	1.2-10.0 (2.8)	.22-1.1 (.57)	.19-2.5 (.87)
Río Guayanés at Yabucoa (0835)[6]	.23-1.4 (.7)	.44-1.6 (.7)	.01-.28 (.09)	.04-.11 (.07)
Río Guayanés above mouth at Playa de Guayanés (0865)[7]	.30-1.2 (.7)	.43-1.1 (.7)	.04-.31 (.10)	.04-.17 (.10)
Río Humacao at Hwy. 3 at Humacao (0820)[8]	.60-4.5 (2.1)	1.1-4.7 (2.0)	.12-.88 (.39)	.02-.78 (.36)

+Source: (58)

1 11 observations and 12 observations for the two periods (10/78 - 9/80, 11/80 - 9/82).
2 6 observations, 10/78 - 8/79; Station discontinued after Aug. 79. Downstream from Añasco.
3 5 observations, 11/79 - 9/80; 12 observations 11/80 - 9/82.
4 6 observations, 10/78 - 8/79, Discontinued Aug. 79.
5 5 observations, 11/79 - 9/80; 12 observations, 11/80 - 9/82.
6 5 observations, 1/80 - 9/80; 12 observations, 11/80 - 9/82.
7 12 observations, 10/78 - 9/80; 12 observations 11/80 - 9/82 (11 observations for N).
8 12 observations, 10/78; 12 observations, 11/80 - 9/82.

TABLE 5

Pesticide Sales Volume in Puerto Rican Sugar Cane Mills.

All data are expressed in units of pesticides which may be either gallons or pounds.

	ROIG					LA PLATA			
YEAR	1978	1979	1980	1981	1982	1980	1981	1982	1983
ACRES	8660.67	7354.43	8029.77	7063.34	76.33.1	11873	11046	12936	11674
PESTICIDE									
AMETRYNE	17028	18205	18048	6844	900				
ANSAR	60	25							
ATRAZINE		2500	1400	810	20				
BENLATE	6								
2,4 D	2142	1734.5	2079.5	1435	1944	2968	2761	3234	2918
DIAZINON	87.5	49	172	64					
DIPEL		392							
DALAPON	17800	18705	22525	9145	5950	23746	22092	25872	23348
HYVAR X	400			45	1000				
DIURON	31150	31852	22683	20839	7363	35619	33138	38808	35022
LINDANE		6075	8005	1848					
PRAMITOL	452	1048	600	265					
GLYPHOSATE				8					
SPEED ALL				143					
STEROX		1113.5	96.5						
SURFACTANTE			1173	865	244				
TRITON X	1493.5	687		55					
VELPAR	100		550	100					
TOTAL	70719	82386	77332	42466	17421	62333	57991	67914	61288
PEST/ACRE	8.17	11.20	9.56	6.07	2.30	5.25	5.25	5.25	5.25

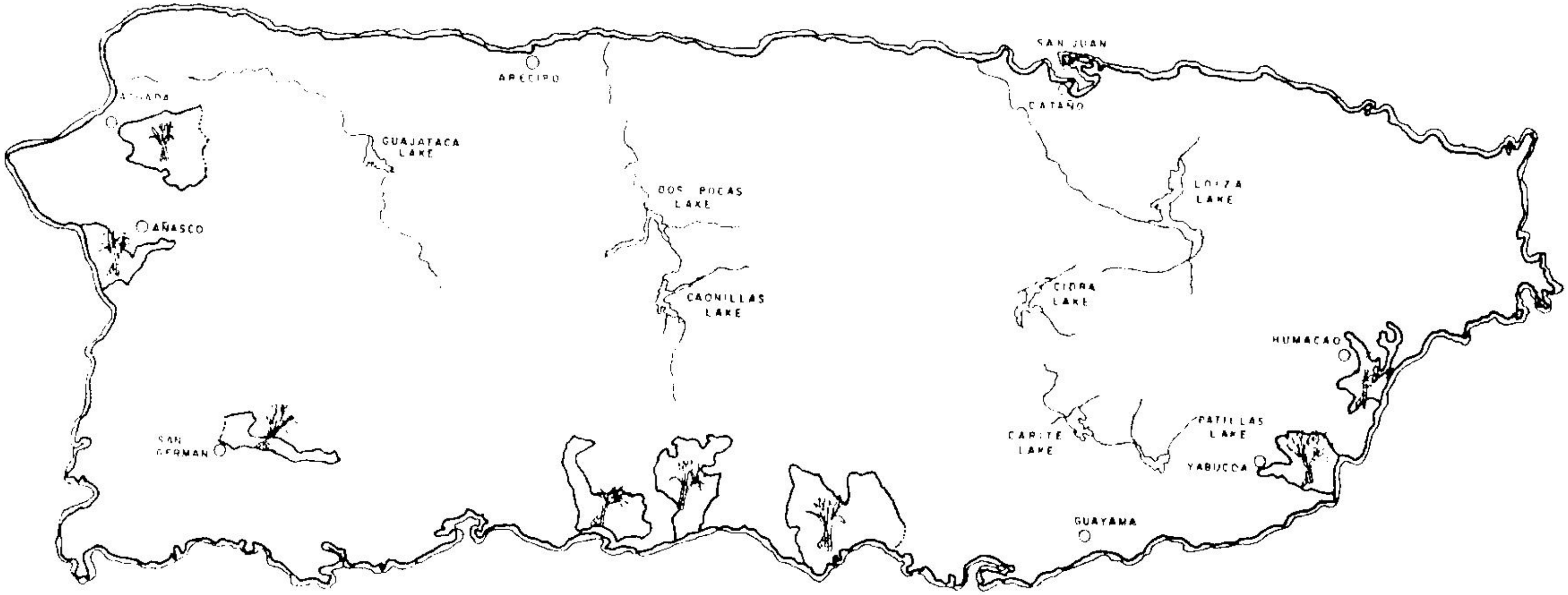
Source: Personal communications with mill managers

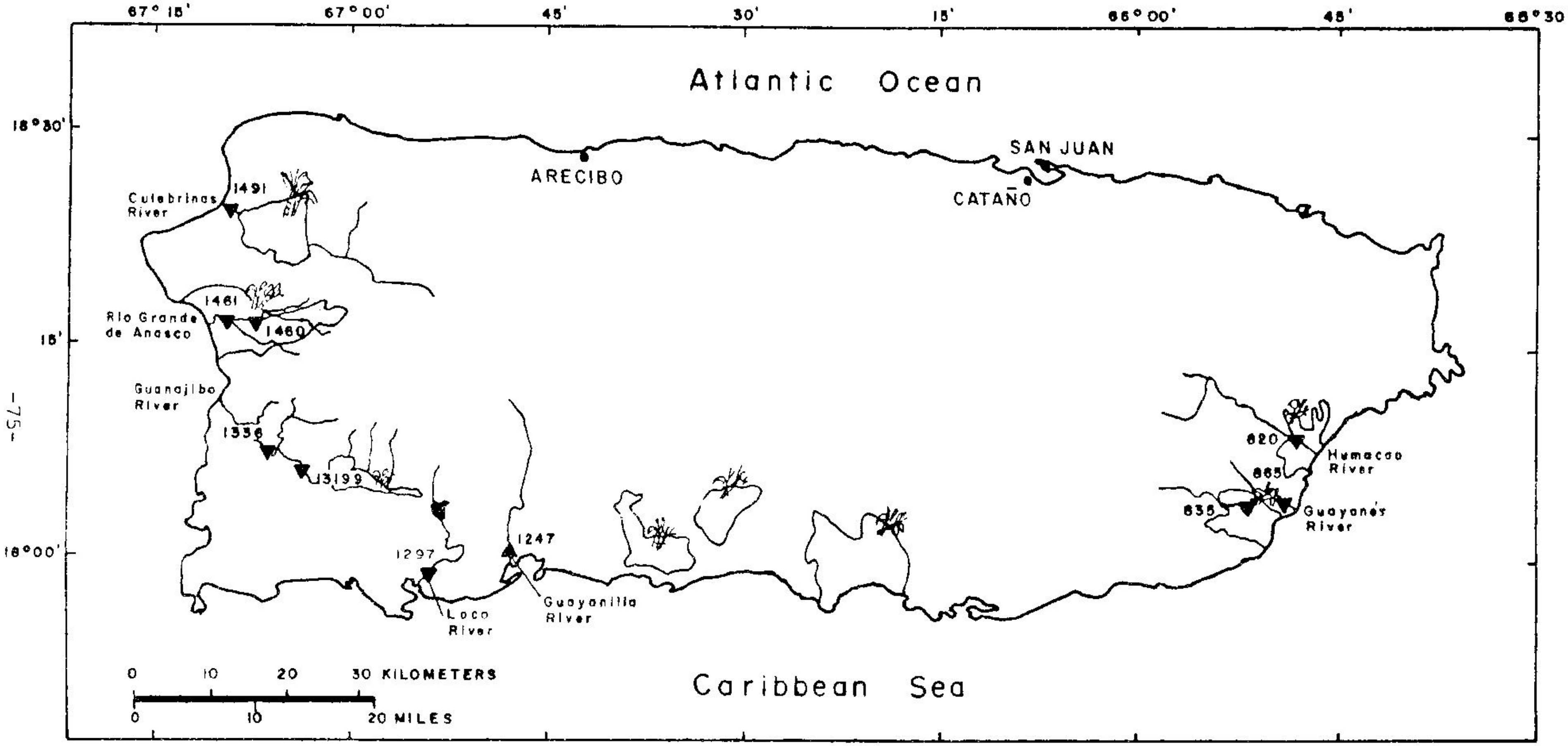
TABLE 6

Concentration of Selected Pesticides in Streams Located Near Sugar Cane Land. Data Adopted from U.S.G.S. Water Quality Years 1979-1982. ND means not detected.

STATION #	DATE TOTAL	2,4 D TOTAL (ug/l)	DIAZINON, TOTAL (ug/l)	LINDANE, TOTAL IN (ug/l)	LINDANE, TOTAL IN BOTTOM MATERIAL (ug/kg)	MALATHION TOTAL (ug/l)	MALATHION TOTAL IN BOTTOM MATERIAL (ug/l)
5008200	6/79				.0		
5008350	7/81		.01	.01		.01	
	7/82		.01	.01		.01	
5001247	12/78				.0		
	6/79				.0		
	8/81		.16	.01		.01	
	7/82		.01	.01		.01	
5001297	6/79				.0		
	8/81		.01	.03		.01	
	7/82		.01	.01		.01	

Map I. LOCATION OF ALLOCATED SUGARCANE AREAS IN PUERTO RICO





Map. 2: LOCATION OF WATER QUALITY STATIONS IN SUGAR CANE AREAS

APPENDIX

Other Environmental Topics

The authors lacked sufficient time to investigate other environmental topics of interest, particularly the effect of energy cane on crumb structure and on salinization of irrigated lands.

Energy cane may permit a better crumb structure than sugarcane because fewer passes are performed with heavy machinery. The organic content of the soil should increase even beyond that obtainable with sugarcane because cane plants tend to produce about as much plant growth below the ground as above the ground. With large increases in yields above ground energy cane should produce substantially larger amounts of organic matter which will remain in the soil after harvesting. Dr. Juan A. Bonnet, Sr. may be of help in determining the effect on crumb structure.

The greater use of well water as well as the possibility of greater use of government-supplied irrigation water raises the possibility of salinization and salt water intrusion into the water table. Ferdinand Quiñones of the U.S.G.S. and William Allison, former head of the UPR Department of Agricultural Engineering should prove useful in this regard. Ariel Lugo might also offer some help.

BIBLIOGRAPHY

1. Alexander, Alex. 1979. "Sugarcane Cultural Modifications for Maximum Biomass" in Alternate Uses of Sugarcane in Puerto Rico.

2. ______________. 1980. "The Energy Cane Concept for Molasses and Boiler Fuels" in Fuels and Feedstocks from Tropical Biomass.

3. ______________. 1982. "Second Generation Energy Cane: Concepts, Costs and Benefits": Presented to the Symposium, Fuels and Feedstocks from Tropical Biomass II, Caribe Hilton San Juan, P.R., April 26-28. CEER.

4. ______________. 1983. "The Energy Cane Alternative to SugarPlanting". Presented to Energy from Biomass and Wastes VII. IGT Symposium Series; Orlando. January 24-28. CEER.

5. ______________. 1983. "Costs and Benefits Assessment of Hatillo Energy Cane: Plant and First-Conservation Crops; 1982-83". April 19. CEER.

6. ______________. 1983. Personal Communication.

7. Allison, William F. 1980. "Soil and Water Management Concepts for Energy Cane Plantations"in Fuels and Feedstocks from Tropical Biomass.

8. ______________. 1983. Personal Communication.

9. Alternate Uses of Sugarcane in Puerto Rico. Proceedings of a symposium sponsored by CEER in collaboration with The Institute of Chemical Engineers and the Association of Sugarcane Technologists, March 26-27, 1979, Caribe Hilton Hotel, San Juan, P.R.

10. Anon. "The Position of the Puerto Rico Rum Producers Association on the Problem of Molasses Scarcity". Puerto Rico Rum Producers Association, Inc. Cited in Samuels, George, "The Molasses Crisis in the Puerto Rico Rum Industry", p. 1.

11. Belardo, Amador. 1980. "Alcohol Research and Development Outlook for Puerto Rico" in Fuels and Feestocks from Tropical Biomass".

12. ______________ .1983. Personal Communication.

13. Boyd, Claude E. 1970. "Vascular Aquatic Plants for Mineral Nutrient Removal from Polluted Waters", Economic Botany Vol. 24; 1, pp. 95-103.

14. ______________. 1976. "Accumulation of Dry Matter, Nitrogen and Phosphorus by Cultivated Water Hyacinths", Economic Botany, Vol. 30, (Jan.-March), pp. 51-56.

15. Brezny, Otto, Indu Mehta, and Ram Krishna Sharma. 1973. "Studies on Evapotranspiration of Some Aquatic Weeds" Weed Science, Vol. 21, 3, (May), pp. 197-204.

16. Committee on Selected Biological Problems in the Humid Tropics. 1982. Ecological Aspects of Development in the Humid Tropics. Washington, D.C.: National Academy Press.

17. del Valle, Manuel Luis. 1983. Personal communication.

18. Fuels and Feestocks from Tropical Biomass. 1980. Proceedings of a symposium sponsored by Biomass Division, CEER, November 24 and 25, Caribe Hilton Hotel, San Juan, P.R.

19. García, René. 1983. Personal communication.

20. Gerloff, G.C. and P.H. Krombalz. 1966. "Tissue Analysis as a Measure of Nutrient Availability for the Growth of Angiosperm Aquatic Plants", Limn. and Ocean., Vol. 11, pp. 529-537.

21. González, Juan G., et al. 1978. Biological Effects of Rum Slops in the Marine Environment. A report by CEER for Environmental Research Laboratory, Office of Research and Development, U.S.E.P.A.

22. Gossett, D .R. and W.E. Norris, Jr. 1971. "Relationship between Nutrient Availability and Content of Nitrogen and Phosphorous in Tissues of the Aquatic Macrophyte, Eichhornia crassipes (Mart.) Solms", Hydrobiologia, Vol. 38, pp. 15-28.

23. Jobin, William R. 1978. "The Ecology of Bilharzia and Agricultural Development in Puerto Rico during the 20th Century", CEER, May.

24. _______________. 1979. "Cost of Snail Control", American Journal of Tropical Medicine and Hygiene, Vol. 28, 1, pp. 142-154.

25. Lugo, A.E., S.A. Jones, K.R. Dugger, and T.L. Morris. 1979. "Ecological Approaches to the Control of Aquatic Weeds", Geo-Eco-Trop., Vol. 3, 3, pp. 193-213.

26. Lugo, A.E., G.R. Ultsch, M.M. Brinson, and E. Kane. 1978. "Metabolism and Biomass of Water Hyacinth-Dominated Ponds and Canals in the Vicinity of Gainesville, Florida", Geo-Eco-Trop, Vol. 2, 4, pp. 415-441.

27. Matsumura, F. 1976. Toxicology of Insecticides. N.Y.: Plenum Press.

28. Nazario, Sonia L. 1983. "Latest of Many Challenges for Bacardí: The CBI", excerpt from Wall Street Journal article of July 29, p. 1, published in the San Juan Star, July 31, p. B-8.

29. Negrón, Edna, 1983. "A Study of Eutrophication and Aquatic Plants Growth in Selected Lakes and Rivers of Puerto Rico", Water Resources Research Institute, School of Engineering, UPR-Mayaguez. Final Technical Report to Bureau of Reclamation, U.S. Dept. of the Interior, March.

30. Negrón Aponte, Henry and Cruz María Nazario. 1977. "The 1976 Skin Test Survey for Schistosomiasis in Puerto Rico. CEER, September.

31. Office of Agricultural Statistics. Department of Agriculture. Commonwealth of Puerto Rico. Facts and Figures on Puerto Rico's Agriculture 1979 - 1980. Santurce, Puerto Rico

32. Office of Research and Development, U.S.E.P.A. 1979. The Rum Industry and Rum Distillery Wastes in Puerto Rico and the Virgin Islands: Effects on the Marine Environment and Treatment Options. 95th Congress Conference Report. No. 95-830. April.

33. O'Neill, Joan. 1983. "Yo-ho, Puerto Rico Now Producing a Spiced Rum", San Juan Star, July 17, p. B-2.

34. Ortega, Norma L. 1983. Phone conversations with CODREMAR officials.

35. Quiñones-Márquez, Ferdinand. 1980. Limnology of Lake Loíza, Puerto Rico. U.S. Geological Survey Water Resources Investigations 79-97. Prepared in cooperation with the Commonwealth of Puerto Rico. February.

36. Raffucci. Francisco. 1983. Personal communication.

37. Reagan, Douglas P. 1980. "Environmental Implications of Biomass and Other Alternative Fuels Usage in Puerto Rico", in Fuels and Feestocks from Tropical Biomass.

38. Rho. J. and H.B. Gunner. 1978. "Microfloral Response to Aquatic Weed Decomposition", Water Research, Vol. 12, pp. 165-170.

39. Ríos, César. 1983. Personal Communication.

40. Rodríguez Benítez, Victor. 1978. "Efecto de la materia prima en la calidad de los destilados de ron", sometido a una reunión científica, Planta Piloto de Ron, Río Piedras, P.R., 17 de noviembre. Mimeografiado.

41. ____________. 1979. "Producción de Mieles Ricas", preparado para someterlo al Senador Hon. Luis Rivera Brenes en reunión con el autor el 16 de enero a las 8:30 en su oficina. Fotocopia.

42. ____________. 1983. Personal Communication.

43. Rodríguez de Zapata, Lillian. 1982. "Situación Actual de la Industria de Ron", Estación Experimental Agrícola, Río Piedras, P.R. Mimeografiado.

44. Rogers, H.H. and D.E. Davis. 1972. "Nutrient Removal by Water hyacinth", Weed Science, Vol. 20, 5 (Sept.), pp. 423-428.

45. Romaguera, Mariano. 1979. "Factory Management Concepts for an Integrated Sugar-Energy Industry., in Alternate Uses of Sugarcane in Puerto Rico.

46. __________. 1980. "Decline of Sugar Refining in Puerto Rico: History and Present Outlook", in Fuels and Feedstocks from Tropical Biomass.

47. __________. 1983. Personal Communication.

48. Samuels, George. 1979. "Land Use Analysis of Puerto Rico", prepared for CEER Biomass Energy Program by Agricultural Research Associates, December 20.

49. __________. 1980. "The Molasses Crisis in the Puerto Rico Rum Industry", in Fuels and Feedstock from Tropical Biomass.

50. __________. 1980. "The Use of High-Test Molasses Distillery Wastes", CEER Biomass Energy Program. April 1.

51. Sheehan, G.J. and P.F. Greenfield. 1980. "Utilization, Treatment and Disposal of Distillery Wastewater". Water Research, Vol. 14, pp. 257-77.

52. Singmaster, James. 1983. Personal communication.

53. Smith, Lewis, 1979. "Multi-Product Output: Key to Bagasse Economics", in Alternate Uses of Sugarcane in Puerto Rico.

54. __________. 1983. Personal Communication.

55. Steuart, D.A., Woolhiser, W.H. Wischmeier, H.J. Caro and M.H. Frere. 1975. Control of Water Pollution from Croplands. EPA Research Series, 600-2-75-026A.

56. Szendry, Michael, Paul Schafer, and George Dorion. 1982. "Pollution and Energy Management through the Anaerobic Approach". Industrial Wastes, Sept./Oct., pp. 31-34.

57. Szendry, Michael. 1983. Personal Communication.

58. U.S.G.S. Water Resources Data for Puerto Rico. Water Year 1979-80 and 1981-82. U.S. Geological Survey Water Data Report PR-79-80 and PR-81-82-1.

59. Vicente-Chandler, José. 1982. Conceptos, plan, y programa para una agricultura moderna en Puerto Rico. Commonwealth of Puerto Rico. enero.

60. __________. 1983. Personal communication.

61. Villares, E.J. 1967. Estudio de Plaguicidas en Algunas Comunidades Puertorriqueñas. Mimeografiado sin publicar. Escuela de Salud Pública de U.P.R.

62. Willis, G.H. and L.L. McDowell. 1983. Pesticides in Agricultural Runoff and their Effects on Downstream Water Quality Environ. Toxicol. Chem. (C4): 267-279.

63. Wolverton, B.C. and Rebecca C. McDonald. 1978. "Nutritional Composition of Water Hyacinths Grown on Domestic S ewage", Economic Botany, Vol. 32,4, pp. 363-370.