LAND USE ANALYSIS OF PUERTO RICO
Prepared For CONVENT RESEARCH
101 Glenridge Key #66
Submitted December 20, 1979

LAND USE ANALYSIS OF PUERTO RICO
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Submitted December 20, 1975

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ABSTRACT
Puerto Rico has an area of 2,189,026 acres, with 901,484 available for agriculture, a population of 3.47 million people, and 0.26 acres of arable land per person. With these dimensions to consider, every acre of land becomes important, for its use directly or indirectly affects everyone, whether the land is chosen for food crops, energy crops, forest, industrial plants or commerce. The outstanding feature of the landscape is its rugged topography with only about 20% of the total area having a slope of 5 degrees or less. The coastal lowlands are the areas of commercial agricultural production, the mountain lands areas of forest and subsistence agriculture, and the rolling intermediates. The soils have undergone recent soil surveys (1965-80) available for agricultural policy and planning. Puerto Rico's agricultural policy for about 75 years has been one of lack of continuity. Its agriculture has not become modern, nor efficient despite costly injections.

The corrected text:

Of funds via subsidies and programs. Agriculture has lost out to industrialization and urban growth, decreasing agricultural acreage. A modern agricultural program developed by the Puerto Rican Department of Agriculture has as its major thesis to produce most of the food it now imports, improve its economy by stimulating domestic agriculture production, and provide employment. New rice, beans, and vegetable enterprises will be established on completely mechanizable land. The cattle industry will be expanded, Tobacco will disappear and sugar production will be downgraded. Commercial forests will be developed. Choices are needed between small and large size farm units. Biomass, plant material to be used as fermentable or combustible solids for recoverable energy, is a new crop that must be considered in land-use planning for Puerto Rico which imports over 98% of its energy. Sugarcane with both combustible and fermentable solids is the most efficient energy crop with tropical grasses (Napier & Sudan 70A) and silviculture "energy plantations" offering viable energy sources. Because of limited land area, balance must be achieved between food and energy cropping. Suggested examples of possible biomass land uses compatible with a modern agriculture program are given. A/ Research Consultant

Puerto Rico has a limited area with large demands placed upon it by a growing population for food and energy crops, living space, industry, and commerce. It is the objective of this paper to give an analysis of past and present land uses in relation to food crops and guidance in developing Puerto Rico's biomass energy cropping. There are simple geographic factors which must govern a land-use analysis of Puerto Rico. Scale - Its extent is 35 miles by 100 miles with an area of 3,435 square miles. Insularity - its frontier is the sea, Density - There are 3.47 million people, 14.10 per square mile with 0.26 of an arable acre per capita, Physiography - 80% of its surface consists of hills and mountains; 20% has to be shared by.

Agriculture, manufacturing, highways, airports, recreational areas, and cities. With these dimensions to consider, every acre of land in Puerto Rico becomes important, as its use directly or indirectly affects everyone. Be it land chosen for food crops, energy crops, forests, industrial plants, housing, or commerce.

THE LAND

1. Physiographic and Geological Features

Puerto Rico may be divided roughly into three principal physiographic divisions (Fig. 1) according to Roberts (1). They are the complex mountains which are the most extensive, the coastal plains, and the beach plains. An east-west mountain range divides Puerto Rico into a northern and southern part. Its crest (about 3,000 feet) is far to the south of a latitudinal line passing through the center of the island. To the south of the crest, the relief is rugged and is characterized by many steep-walled rock cliffs, abrupt high waterfalls, and jagged peaks. On the north side of the crest and extending to the coastal plain, the relief gradually becomes less rough.

The coastal plains parallel nearly the entire coastline. They range in width from a maximum of 13 miles at Lares to nil at several points along the eastern and western coasts. Most of the coastal plains are confined to areas that are covered by a thick deposit of limestone that several fluctuations in sea level in the past have caused the landscape to have a belted appearance. Erosion has produced numerous hills and valleys. The beach plains include the level alluvial plains, lagoon deposits, and elevated beach sands. The flat alluvial plains occupy the largest area and comprise the most valuable agricultural land. They occur along all the streams, but are most extensive near the mouths of the large rivers.

Betancourt (2) uses Mitchell's seven physiographic regions to describe the physiography of the island in more detail.

2. Landform and Topography

The limitations and potentials of agricultural development are largely determined by the island's physical characteristics. The

An outstanding feature of its landscape is its rugged topography. Only about 20% of the total area has a slope of 5 degrees or less. The land area by percent slope is given in Table 1.

Mae Young (4) identified 12 different landform areas based on local relief, percentage of steep slope, and percentage of flat land. The three major landform classes defined were lowlands, hill lands, and mountain lands. In percentage of total area, they are as follows:

Lowlands - 19%
Lowlands - 11%
Rolling Lowlands with some flat land - 22%
Rolling lowlands - 8%
Hill lands - 37%
Rolling hill land with some flat land - 4%
Rolling hill land - 22%
Rough hill land - 42%
Rugged hill land with some flat land - less than 1%
Rugged hill land - 62%
Mountain lands - 47%
Rolling mountain land - 6%
Rough mountain land - 15%

Rugged mountain land - 23%

A description of these landform areas is given by Fields (3, pp. 99-101). Fields superimposed 11 rainfall regions on Young's 12 landform regions to give seven land-form-climatic regions for the island that is meaningful from the standpoint of agriculture (Fig. 2). At the risk of over-generalization, the flat lowlands may be characterized as the area of commercial agricultural production, the mountain lands as the area of forests and subsistence farming, and the rolling lowlands and hills as intermediate between the two, characterized by mixed, small-scale commercial agriculture and subsistence farming.

Land area in Puerto Rico distributed by altitude is as follows (3):
Flat at level of land area: 352 sq. miles
500-999: 1000+ sq. miles - 2%

Though 55% of its land area, 1.2 million acres, is under 500 feet in elevation, the percentage of flat land is substantially less with only 400,000 acres having slopes of acreage in subject to constraints in cultivation as a result of such factors as erosion, drainage, and climatic conditions. The significance of the flat land lies in its suitability for mechanized agriculture.

The soils of Puerto Rico have been thoroughly classified. The first detailed

The survey of the Island was completed by R. C. Roberts and party in 1936 by the Division of Soil Survey, Bureau of Plant Industry, USDA (1). This soil survey is comprehensive, covering both crops and soils. It still serves as a handy reference for anyone wishing to know Puerto Rican agricultural status before 1936. The Robert's soil survey was updated by the Soil Conservation Service (SCS), USDA beginning in 1965 with a survey of the Lajas Valley area. Since then, additional soil conservation districts have been covered, with the Arecibo district set to be published in 1980. The districts covered and their acreages are as follows:

Arecibo District (6) 470,202 acres

Lajas (7) 102,609 acres

Yauco (6) 460,836 acres

Ponce Sur (8) 171,790 acres

Caguas Caribe (10) 123,613 acres

San Juan (11) 447,279 acres

TOTAL acres: 2,274,094

The recent (1975-1980) soil survey is quite comprehensive and it provides more than a mere classification of soils. The make-up of the soil survey for a conservation district contains:

1. General nature of the area and climate.
2. General soil map for broad land-use planning with map unit descriptions and soil associations.
3. Description of the soils, describing each soil series in detail, and then briefly, for layman use, each mapping unit in that series.
4. Use and management of the soils. This section contains an explanation of the system of capability grouping used by the SCS. Estimated yields for the principal crops and pasture grasses under two levels of management (local and improved) are given. Management of the soils for woodland is also discussed. Information and limitations that affect engineering practices and recreational uses are presented in tables. The information and classification of the soils as to major factors of soil formation are given with the definition of the system currently used for classifying soils by the six higher categories of order, suborder, great

Group, subgroup, family, and series. A table is included of the classification series, giving the family, subgroups, and order for each.

The soils are grouped at three levels: the capability class, subclass, and order. In the broadest grouping are the eight capability classes designated by Roman numerals I through VIII. The first class includes the soils that have few limitations, the widest range of use, and the least risk of damage when they are used. The soils in the other classes have progressively greater natural limitations. In class VIII are soils and landforms so rough, shallow, or otherwise limited that they do not produce worthwhile yields of crops, forage, or wood products. The subclasses indicate major kinds of limitations within the classes. They are (e) erosion, (w) water or poor drainage, (s) shallow, droughty, or stony, and (c) climate too dry. The capability classification unit for each soil is listed in the "Guide For Mapping Units" and at the end of the mapping unit description in the section, "Description of Soils" in the Soil Surveys of Puerto Rico (6-21).

The soils of Puerto Rico were grouped by Vicente-Chandler (5) in 1978 in accordance with their agricultural potential. The grouping is stable and usable within the framework of the soil mapping units of the land capability classification of the SCS. The soils are divided into five groups (Table 4). This grouping has served as the basis for the modern agricultural program now being carried on by the Commonwealth Department of Agriculture. It is a very useful grouping that can be used as a base for land-use assignments of crops, silviculture, and other agricultural enterprises including energy crops.

Knowledge of the status of the land-use inventory of Puerto Rico is of both vital and urgent planning. The Department of Natural Resources made a land-use inventory of the island. The inventory was made from aerial photographs and two computer programs which allowed determination of the land use to a detail of 62 acres. They obtained agricultural acreages of 1,176,816 and forest 102,278. The acreage of agricultural land suitable for mechanization is an important factor in land-use decisions.

Vicente-Chandler (5) estimated 337,000 total acres (276,000 available acres allowing 20% off for roads, housing, etc.) of land that can be used for fruit mechanization. This is primarily class T land and under irrigation or adequate rainfall available. Sonnet (22) stated that some 523,191 acres,

about 24% of Puerto Rico's total of area, are suitable for mechanized planting of sugarcane, whether for sugar or for total biomass (Table 5). This includes class TI, and some 21 lands with slopes 20% or less.

The Puerto Rican ecosystems are extremely important because they form a substantial component of the life-support system for over three million people. Ewel and Whitmore (16) mapped the ecological life zones for Puerto Rico according to the Holdridge system. They identified six distinct life zones which are also widely represented in Central and South America. Detailed emphasis was given to ecological zone features, water balance, and biotemperature theory so that research done in Puerto Rico, Central America, and South America will be mutually beneficial.

The areas occupied by the ecological life zones in Puerto Rico are (15):
* Subtropical Dry forest 300,578 acres
* Subtropical Moist forest 1,315,105 acres
* Subtropical Wet forest 325,087 acres
* Subtropical Rain forest 3,262 acres
* Subtropical Lower Montane Wet forest 26,959 acres
* Subtropical Lower Montane Rain forest 3,939 acres

The subtropical moist and wet forest zones occupy 57% of the total land area in Puerto Rico. More thorough study has been given to the systems of Puerto Rico and the Virgin Islands than to most other tropical regions. The ecological studies made of Puerto Rico prior to 1900 were summarized by Wadsworth (17) in 1950. Murphy (18) was one of the first to provide detailed descriptions of Puerto Rico's forests in 1916. A classic description of the island’s plant communities was published by Cook and Gleason (19) in 1926, which still serves as a standard reference work. In 1965, Dansereau (20) published physiognomic and floristic descriptions of more than 100 vegetation types.

Types in Puerto Rico designate six principal vegetation zones conditioned primarily by climate and secondarily by either physiography or plant material. Publications with accompanying maps of vegetation were issued by Little and Wadsworth (21) in 1964, by Williams (22) in 1967, and by Odum and co-workers (23) in 1970. A meaningful land-use analysis of Puerto Rico should include a brief discussion of its climate, for its climate, primarily as related to rainfall and evaporation, influences a great deal of the agricultural usage of the land.

The island is subjected to a humid, oceanic climate, and normally experiences heavy precipitation over most of the area. The highest peaks and the northern and eastern sides of the mountain ranges receive the most rainfall (Fig. 3). The southern side, northwestern corner, shoreline and the interior valleys receive the least. The average annual rainfall ranges from less than 30 inches in the south eastern part of the island to nearly 200 inches on the highest peaks in Sierra de Luquillo (Fig. 4).

There are no definite seasons, but rather a rainy period from May to November and a dry period the other six months. Throughout the winter, however, many showers occur, the heaviest torrential rains take place in the summer. The high evaporation rate combined with high temperatures, low relative humidity, and constant winds tends to cause semi-arid conditions even where the average

annual rainfall is 45 inches.

A rainfall of 39 inches in Puerto Rico is equivalent in effectiveness to about 15 inches in the United States. Many of the agricultural areas on the southern coastal plain have evaporation rates much higher in comparison to their rainfall during the dry weather than other seasons, and irrigation is necessary even in areas having an average annual rainfall of 65 inches (Fig. 5).

The water available from dams, wells, and rivers must face competition with domestic and industrial consumption, thus limiting supplies available for irrigation. A water balance for the semi-arid southern region reveals an imbalance.

Average 5 million gallon per day deficit (Table 6). The mean monthly temperature varies by no more than 5°F from summer to winter. Yearly mean average temperatures range from 77-79°F on the coastal plains to 71-74°F in the mountains. The temperature seldom rises higher than 90°F and even in the highest, coolest parts of the island, it seldom falls below 50°F. Sunshine is a daily occurrence over most of the island with the exception of a few days each year. Temperature and sunlight are not limiting factors for agricultural production in Puerto Rico. Rainfall is limiting in some areas of the south and southwest coasts during the winter months, but irrigation, when available, compensates for this water deficit.

Agriculture has always been a key part of Puerto Rico's past. Since the days when the island was first settled by the Spanish, the people have been concerned with producing agricultural crops. Up until the twentieth century, the agriculture in Puerto Rico, as in most of the Caribbean, was based on large farms or plantations, owned by a few, growing sugarcane, tobacco, cotton, and fruits for export. Domestic food was grown on small plots by the farm laborers. In 1900, when Puerto Rico became a U.S. possession, Congress passed a law limiting land holdings to no more than 500 acres by any individual or corporation. The law was not enforced, and large land holdings continued. Some of the agricultural policies of the U.S. government in the early 1900s were applied to the island, with soil and water conservation programs beginning in 1923, the WPA programs in the 1930s, and the Farm and Home Administration Program of family farms of 30 to 40 acres in 1948. The change of political climate in the early 1940s, with the beginning of the Popular Democratic Party of Muñoz-Marín, marked the start of the local Puerto Rican agricultural policy. In 1961, the island's legislature passed the land law (Ley de Tierras). It reaffirmed the 500-acre limitation law.

At this time, sugarcane occupied over...

70% of the crop acreage, with the major part being contracted by companies, were in Puerto Rico. The 1941 Land Law established the Land Authority of Puerto Rico, a semi-functioning part of the Puerto Rico Department of Agriculture. Its task was to end large corporate land holdings, help small farmers, encourage new farmers, and make best use of the lands for public good under efficient and economic production. The Land Authority handled the disposal of the large Proportional Benefit Land (Title IV) consisting of large commercial farms and sugar mills organized and run by the Authority. These were mainly devoted to sugarcane; small plots (1-7 acres) were distributed to low-income families (Title V); and family plots of up to 25 acres were sold to farmers (Title VI). Since the creation of the Land Authority in 1941, the island's agriculture was subjected to many

plans, programs, and reports evolved to help formulate a sound and dynamic agricultural policy.

High points identified by year are summarized as follows:

1953 - "A Comprehensive Agricultural Program for Puerto Rico" was drawn up by Dr. Ns Koenig, USDA, with the cooperation of the Commonwealth of Puerto Rico (24). This study was most thorough in its examination of soil erosion, water use and control, reclamation, forest and grassland resources, as well as its analyses of agricultural credit, marketing problems, farm size, unemployment in rural areas, and the problem of land use and taxation. Many of the technical findings and recommendations remain useful and valid today. Nevertheless, the study's usefulness as a guide to the formulation of a development strategy for agriculture was weakened because it incorrectly assessed the impact of factors external to agriculture, mainly industrialization. Wrong conclusions were drawn because it divorced agricultural planning from the mainstream of development decisions for the Island as a whole.

1966 - "The Future of Puerto Rico: Current Form and Possibilities" (25) was presented by the Secretary of Agriculture.

Nick-Agreste, in collaboration with local scientists, made recommendations concerning agricultural policy and outlined a program of sectors for the development of many aspects of Terra Instituting. Among the funds, conservation of water, soils, and forests, drainage projects, and increasing the agricultural budget were included. Parts of the program were pieced together, but not with unified long-range planning. Over time, various agricultural secretaries have given impetus to distinct parts of the program, in accordance with their criteria and the situations of their time in office.

Agricultural Land #9 was subject to a study by the Land Management Society and Agricultural Senate. The report was drawn up to examine the problems affecting agricultural land ownership and to recommend measures to ease the impact of zoning laws on productivity. A model was developed to serve as a basis for farm classification. The study was limited to data from 1963, specifically for the Yauco area. The report contains a good general description of climate and topography (pages 101-104) and a review of soil area characteristics (Appendix 3). No significant action was taken on this report by government authorities, despite the dire need for a clear policy on zoning to preserve the good agricultural lands of Puerto Rico.

It appears that the agricultural policy and planning for Puerto Rico for about 75 years has been one of lack of continuity. The past policies were limited to responding to a succession of crises in different sectors rather than any long-range planning. The island's agriculture has not become modern, nor efficient, despite the injection of funds during the last quarter of the 20th century.

A comprehensive review titled "Projects for a Modern Agriculture in Puerto Rico" was developed by J. Vincente-Grande with the aid of consultants and submitted to the Commonwealth Department of Agriculture as a guide in developing a complete long-range plan for agriculture. The end.

"Heads of the 94 that Puerto Rico requires a modern progress to fully utilize water, and year round cultivation of the food it now imports, improve its economy by stimulating domestic agriculture, education, and provide employment, but not at the price of rising costs. The report doesn't rely on generalities, it presents definite recommendations as to crop and land needs, economic demands,

farm employment, and a timeline for development by 1988 to stimulate food production and minimize product losses. The goals are based on modern farming with agronomic supervision to bring the latest technology directly to the farmer. The plan has designated some drastic changes in land use, as modern agriculture develops over the next 19 years. The area in sugarcane will be markedly reduced and will be limited to completely mechanizable lands. The new rice, vegetables, and bean enterprises will be established on completely mechanizable land. Pineapple and hay production will be expanded on the mechanizable lands where they are now concentrated. The production of pigeon peas and starchy vegetables will be transferred from sloping lands to mechanizable lands. The tobacco industry will disappear. The production of coffee, citrus, bananas, and plantains will be concentrated on moderately steep soil. The livestock industry will be developed on soil in the semi-arid region, the production of poultry, pigs, and ornamentals will expand mostly on soils with moderate slopes in the rain-fed region and on mechanizable but very sandy soils. Commercial forests will be developed mostly on steep, deep soils which are at present largely abandoned. Aquaculture will be developed in appropriate areas and the very steep, shallow soils will be kept as natural woodlands. In Table A, the total acreage for each agricultural enterprise, the production goals projected for 1988, and the farm values are presented. The total value of agricultural production at the farm level is projected to increase from $421.3 million in 1976 to $793 million in 1988."

(2) Human Resources. Puerto Rico's human resources comprised a population of 3.47 million in 1979, projected to an estimated 3.58 million in 1986 (p.5). The land area is 3,435 sq. miles and will not grow any larger. This gives a population of 1,010 people per sq. mile, giving it a population density greater than Japan and about the same as Taiwan. It becomes impossible to make any decisions in land use for agriculture without consideration of this dense population.

Density. On average, 47,000 out of 718,000 individuals work in agriculture. The majority of these individuals are over 44 years old and have an average of 4 years of schooling. On the other hand, more than half of the island's population is less than 19 years old and more than 400,000 workers are high school graduates. The modern agricultural program in 1958 will employ an estimated 47,000 people at reasonable salaries throughout the year (Table 5). This includes farm workers, farmers, and farm managers. An additional 40,000 jobs will be generated from this agricultural endeavor, bringing the total to 88,000 jobs.

The major agricultural sector in Puerto Rico has the necessary resources to drive an effective and continuous effort. As pointed out before, overcoming obstacles is crucial for progress. Historically, due to its agricultural past, the best lands were transformed into large holdings with only a small percentage of the total acreage being farmed. Various administrations have tried to create a balance between large and small farms. The government may need to create small farms using grants. At present, despite the decline of the sugar industry, the government continues to invest. The farm sizes for the island in 1976 are given in Table 2. Over 86% of the farms were below 30 acres, but this represented only 24% of the total farm acreage. There were 672 farms (2.9% of the total number of farms) over 260 acres, which represented 50% of the total farm acreage. Interestingly, compared to 1950, the number and acres of small size farms are decreasing and the larger-size farms increasing. Modern agriculture requires large-size farms for certain crops (sugarcane, rice) and small-size farms can do well in intensive and specialized crops and enterprises (ornamentals, poultry). The modern agricultural plan appears to be searching for a

balance of various farm sizes suited to the type of enterprise. The political advantage of this strategy is yet to be determined.

Small-size farms must be weighed against the practical reality of the skills of the farmer, his resources, and the viability of the agricultural market he must deal in.

The forests of Puerto Rico have played an important role in protecting soils, reducing the amount of soil erosion and water resources by simply protecting runoff into periods of dry weather. When the island was colonized in the early 1550s, it was covered with forest, but clearing for farms was soon begun. By 1930, most of the forests had been cut. Some of these areas were abandoned and were taken over by inferior vegetation species. About 1. million acres of land are available for forest cover in Puerto Rico. A study (13) showed fine wood growth at 682,000 scattered crown 32,065 acres, solid crown cover 264,493 acres and public forests 125,67 acres. Commercial and non-commercial forests including the Caribbean National and Commonwealth forests require about 50% timber stand improvement or reforestation. Woodland-sustainable groups have been compiled by the soil surveys for Puerto Rico to assist in planning the use of the soils for good crops. Woodland management plans include such specific data as woodland suitability, soil group and map symbols potential productivity, planting suitable trees and average yearly growth per acre in board feet, and the hazards and limitations that affect management, including seed mortality, erosion hazard and equipment limitations. Using the soils for forests involves more in changing of some natural non-commercial forests to commercial, the protection of other non-commercial forests in their natural state, and the planting of non-forested areas. About $250 million worth of wood products are imported yearly; yet, there is no local wood industry. The modern agricultural program recommends that 220,000 acres of the 280,000 acres of the mountainous steep, deep soils be established in commercial forests over the next years.

Forestry experts have recommended that...

Honduras is a site for commercial growth in Guava Rice. These forests will produce wood with a face value of $63 million yearly and will create 4,000 jobs in the field's growth. Introduction: Until 1979, any land-use analysis study of Puerto Rico would concern itself with acreages of food crops, pastures, and forests for its various soils. The world energy crisis has added a new dimension to any planning, be it political, economic, or agricultural. To address these crops, a new word has been added: Biomass. Biomass can be defined as plant material that has the ability to convert radiant energy of the sun to chemical energy and to store this energy in recoverable forms (fermentable and combustible solids). Thus, biomass as an agricultural crop gives man a renewable energy source to replace dwindling supplies of fossil fuels. There are two principal groups of biomass: herbaceous annual species and woody perennial species. The herbaceous group includes the major part of our agricultural crops such as sugarcane, forages, grains, vegetables, and starchy root crops. The perennial group includes such crops as coffee and citrus, but most woody plants are forestry (or silviculture) species. Biomass becomes available for energy sources by burning its combustible solids as a boiler fuel, converting its fermentable solids to alcohol-based fuels, use of pyrolytic methods to produce gas and liquid fuels, and development of chemical conversion of cellulose and hemicellulose complexes to alcohol or chemical feedstocks. Thus, agricultural planning in Puerto Rico must consider such crops as sugarcane, tropical grasses, and silviculture, not only for their conventional uses, but for their energy potentials.

Puerto Rico imports over 96% of its energy requirements as oil. With the world energy crisis sending oil prices soaring, the expenditure for oil in 1976 was $1.4 billion (USD). Food expenditures for imports amounted to $500 million for the same period. However, oil prices are rising at a more rapid rate than food crop prices.

Solid can be used for alcohol production directly from the cane juice or from molasses. Thus, every 169 tons of fresh cane becomes 130 tons of biomass cane (30% of the leaves and tops) which gives 22 dry tons of biomass cane or 189 tons TU equivalent to 36,000 kW of electricity; plus about 1,600 gallons of alcohol from cane juice or enriched molasses, sufficient to replace 1,600 gallons of gasoline. (®) Tropical grasses, among others, show promise as maximum biomass producers. Napier grass has been shown by Alexander to produce more biomass tonnage than sugarcane in a 6-month harvest interval (31). It can be designated as an intermediate rotation crop suited in areas not appropriate for sugarcane, because of the length of the growing season or other conditions such as rainfall. A crop appropriate for short rotation is the hybrid forage grass, Sorghum 70A, a cross between sweet sorghum and Sudan grass. Alexander (31) has obtained an average of 3.4 tons per acre projected oven-dry biomass in 2-month harvest intervals and 4.3 tons in a 4-month harvest interval. Sorghum 70A is versatile and can fit rotation with many food crops. "Wild Saccharum clones (US 67-22-2 and SHS £51) and Jowar grass (Sorghum vulgare) have been suggested for maximum yield candidates for marginal soil where lack of water is predominant (30). They can produce moderate yields under minimum production inputs. The potential for Puerto Rico's forests has never been realized when managed as "energy plantations". However, Whitmore and Alexander (42) foresee a new dimension and challenge in the production of total dry matter for energy conversion rather than timber. A pilot research project has been submitted to the USDOE, Fuels from Biomass Systems Branch. Potential projections of 18 tons dry matter/acre/year for tropical rainforests have been suggested (33). Certain species of the genera Euphorbia, Salicornia, Capparis, and Parthenium might also contribute.

Sorghum on marginal lands because of their high content of plant hydrocarbons (32), rather than as a buffer for 3. In terms of food and energy cropping, agricultural planners in Puerto Rico must weigh carefully the merits of energy planting versus food planting for the island's available land resources. There are about 270,000 acres of level, mechanizable land for either cropping system or a combination of both. This is the best land and is capable of producing the highest yields of food or energy crops.

Yet compromise can prevail to give a rational combination of both. Some suggested examples of possible biomass land uses compatible with a modern agriculture program are:

1. The proposed 70,000 acres of sugarcane in the modern agriculture plan can produce, instead of sugar at a loss, boiler fuel (bagasse) and enriched molasses sufficient to supply all the needs of the Puerto Rico rum industry, with a significant surplus which can be converted to alcohol for gasohol, saving on imports of both molasses and motor fuel.

2. The use of tropical grasses such as Napier on the humid, deep soils with 20-25% slope could provide more BTUs of energy as a boiler fuel than all of the 522,000 acres of soils that could be planted to sugarcane (Table 10) including the best slopes for mechanization. Of course, not all the 554,000 acres of the humid, deep soils with 20-25% slope can be used for Napier grass, but aside

from slope, the soils and climate are good for Napier grass production.

3. The use of Sorghum 70A, not only in the semi-arid gentle rolling hills for three crops per year, but in any cropping area where there is fallow for 2-3 months before planting the next crop (such as for vegetables).

4. The use of silviculture to produce boiler fuel instead of lumber. There are about the same number of BTUs available on these non-food croplands as on those available for sugarcane energy crop production (Table 10). The steepness of some of the 736,000 acres would prevent its use for biomass production. If we allow 29% of the

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Percent of Total Area in Acres:
0-5: 393,196 (19.2%)
6-15: 373,312 (18.4%)
16-35: 333,838 (16.3%)
36-45: 372,372 (38.1%)
46-59: 172,266 (8.4%)
60+: 608,372 (30.0%)

Total: 2,051,258

Note: This excludes approximately 2,550 acres in urban or unproductive use as well as the land area of the islands of Culebra, Vieques, and Mona.

2/ After Field (a).

Corrected Text:

Table 2: A Brief Description of the Soil Orders of Puerto Rico for Guiding on the New Taxonomic System

2.1: Ultisols not developed yet (organize) work in unison with stratosphere clay minerals. Oxisols have a reddish-brown hue in alluvial horizons with Vertisols. Cloves subhorizon more acidic than surface. All derived from (22).

2.2: Very rare in Puerto Rico. Features are affected by frost and high water tables on sloping terraces. Soils having high base saturation: cracking and clayey accumulation of Al, with no organic matter in the second sub-zone.

Organic soil acid with low base exchange capacity; advances in the stage of weathering, a mixture of hydrated oxides of Al or Fe, or both, with a variable amount of kaolinitic clay and insoluble quartz. Generally good drainage, acid with low base exchange status and capacity in regions of high rainfall; where leaching exceeds base liberation, low persistency.

Table 3: Acreage and Percentage Distribution of Soils by Order in the Six Soil Survey Areas of Puerto Rico

Note: Acreages and percent distributions for each area are not listed due to the original text being unclear.

Table 4: Soil Resources of Puerto Rico Grouped by Accordance with their Seacoast Area

4.1: Soils of the flat coastal region (All deep, alluvial soils are suitable for sugarcane, rice, and starchy vegetables). Net acreage - 123,408. Gross acreage - 103,326.

4.2: Deep, red soils (Suitable for pineapples, sugarcane, starchy vegetables, and dairying). Net acreage - 18,112. Gross acreage - 94,490.

4.3: Soils of the Guan ‘Cleus, dairying. Net acreage - 34,392. Gross acreage - 107,674.

4.4: Soils of the hilly mountain region. Deep soils with SOR stoves (Suitable for coffee, plantation, sugarcane, rice, dairying, beef cattle). Net acreage - 696,640. Gross acreage - 495,222.

Note: Medium deep soils were not specified in the original text.

All data derived from source (12, Table 7).

Areas with 50% slopes (Commercial Forest) 350,578 280,462 F. Shallow gullies or steep slopes (Guaraguao Woodlands, Wildlife, Recreation) 283,106 227,585, (Natural Woodlands, Wildlife, Recreation) 101,740,408 TY. Soils of the sun-lit sector N. Beech, Covers Jersey, Irrigable Sites (Cotton, Beans, Few Crops) 5,500 are Series versus the 4 Consecrated Olive (Orange, Avocados, and other fruits) 2,500 39,322 K. Steep shallow soils (Natural Woodlands, Wildlife, and Recreation) 220,016 230,016 V. Side of the coastal lowlands with draining sands, many of them sandy (Aquaculture, Ecological Reserves) 26,850 26,050 2,109,026, 1,817,415 A/F discounted for rent, industrially Low crop fund Le.

TABLE 5. ACREAGES AND PERCENT DISTRIBUTION, BY ORDER, OF MECHANIZED AND NON-MECHANIZED SOILS OF PUERTO RICO 1/.

Order Mechanized Non-mechanized Total
Entisol 61,286 (2.8) 37,208 (1.7) 98,492 (4.5)
Inceptisol 118,190 (5.4) 726,652 (32.2) 844,842 (38.6)
Alfisol 45,963 (2.1) 45,963 (2.1) 92,926 (4.2)
Ultisol 96,303 (4.4) 120,379 (5.5) 226,682 (9.9)
Vertisol 52,529 (2.4) 0 52,529 (2.4)
Spodosol 2,189 (0.1) 0 2,189 (0.1)
Histosol 4,377 (0.2) 0 4,377 (0.2)
Oxisol 4,586 (0.2) 4,327 (0.2) 5,913 (0.2)
Mollisol 11,626 (0.5) 396,187 (18.2) 507,813 (23.2)

Totals 534,065 (24.4) 1,930,735 (75.8) 2,464,800 (100)

TABLE 6. AVAILABLE WATER CAPACITY FOR THE STANDARD REGION OF PUERTO RICO (EXCLUDING THE LUCAS VALLEY) IN MILLIONS OF GALLONS OF WATER (TABLE 1)

Municipality Available Agriculture Domestic Negative Balance.

TABLE 9. NUMBER OF FARMS AND ACREAGE BY FARM SIZE, 1974

Size Number of Farms Acreage of Farms
Actual % of total Acres % of total
Less than 3 2,782 5.4 4,061 0.3
4-9 14,597 38.9 59,8 4.9
10-19 5,083

I'm sorry, but the text you've provided is too scattered and unclear for me to correct. It seems to contain a mixture of numbers, abbreviations, and incomplete sentences. Could you provide more context or a clearer version of the text?