

Trends in fertilizer consumption in Puerto Rico^{1,2}

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ABSTRACT

Modern agriculture must strive to maximize yields, crop quality, and profit in the most sustainable manner. The rational use of fertilizer is one of the most influential factors affecting these traits. In this paper, we examine trends in fertilizer consumption on global, regional and local scales and describe the possible reasons for the trends in fertilizer consumption in Puerto Rico. World fertilizer consumption has more than quadrupled since the 1960s. Fertilizer consumption in most regions is either stable or increasing, with the biggest increase occurring in Asia. In contrast, the annual rate of fertilizer consumption in Puerto Rico was -2,740 t/yr, for the period between 1990 and 2006. Fertilizer consumption rates (in kg/ha) in Puerto Rico lag behind those of other countries in Latin America and elsewhere. The decrease in annual fertilizer consumption is primarily related to reductions in agricultural land-area (as defined by the Food and Agriculture Organization, FAO), and to a minor extent, to lower fertilizer rate applications. The latter suggests that most farmers are not fertilizing to maximize yields.

Key words: fertilizer consumption, fertilization of tropical crops, sustainable agriculture

RESUMEN

Tendencias en el consumo de fertilizantes en Puerto Rico

La agricultura moderna debe maximizar los rendimientos, la calidad de las cosechas, y la ganancia económica en la forma más sostenible posible. El uso racional de los fertilizantes es uno de los factores de mayor influencia sobre esas características. En este trabajo, examinamos tendencias en el consumo de fertilizantes a nivel global, regional y local, y las razones

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por las cuales se observan las tendencias de consumo en Puerto Rico. El consumo mundial de fertilizantes se ha cuadruplicado desde la década de 1960. El consumo de fertilizantes en la mayoría de las regiones del mundo es estable o continúa en aumento, con el mayor incremento observado en Asia. Esta tendencia contrasta con el consumo de fertilizantes en Puerto Rico, donde la tasa es de -2,740 t por año, para el período entre 1990 y 2006. Los niveles (kg/ha) de consumo de fertilizantes en Puerto Rico son inferiores a los de otros países en América Latina y otras regiones del mundo. La disminución en el consumo de fertilizantes se debe principalmente a la reducción en el área total agrícola (según la definición de la 'Food and Agriculture Organization' de las Naciones Unidas, FAO) y por reducciones en los niveles de fertilización. Lo último sugiere que muchos agricultores no están fertilizando lo suficiente para maximizar sus rendimientos y para mejorar la calidad de la cosecha.

Palabras clave: consumo de fertilizantes, fertilización de cultivos tropicales, agricultura sustentable

INTRODUCTION

Global grain production has more than doubled since 1960 and continues to be on the increase (Godfray et al., 2010). The increase can be attributed to a 12% world cropland area expansion, use of high-yielding cultivars, chemical fertilizers and pesticides, mechanization technologies, and expanding irrigation (Foley et al., 2005). Reports differ as to how the world's ability to produce food will be affected by growing competition for land, water, and energy in the next forty years. Global world population annual growth rates for 2011 are estimated at 1% and are expected to reach nine billion people by the middle of the twenty-first century (US Census Bureau, 2011). Additionally, many in the growing population are expected to be more affluent and will have a larger demand for processed foods. Overall, fluctuations in food prices are expected to be more frequent, land demand for biofuel production is expected to increase, whereas agricultural land-area is expected to remain relatively unchanged (Foley et al., 2005; Fedoroff et al., 2010; Godfray et al., 2010).

An important challenge in the global food balance has been to match world food supply with demand. The fact that today nearly 985 million people are malnourished constitutes clear evidence of this assertion (Godfray et al., 2010). To eliminate world hunger, agricultural production must be increased through improved crop yields and quality. It has been estimated that at least 30 to 50% of crop yields world-wide can be attributed to the use of commercial fertilizer nutrient input. In highly weathered soils of the tropics, this contribution may reach 80 to 90% (Stewart et al., 2005). Technological advances in agriculture have secured high food production per unit of land area (FAO, 2004), yet these advances have also caused extensive environmental damage (Parry,

1998; Sharpley et al., 1999; Rabalais et al., 2001; Postel, 2005; Snyder, 2008). The sustainable management of nutrients involves keeping a balance among nutrient ratios (Vicente-Chandler et al., 1983), nutrient budgeting to avoid soil fertility depletion or surplus (Mulvaney et al., 2009; Bast et al., 2009) and a cost/benefit assessment (Vanotti and Bundy, 1994; Stewart et al., 2005).

Puerto Rico constitutes an interesting case study from the standpoint of agricultural production and nutrient management. After the 1950s the island experienced a dramatic structural transformation from an agricultural to an industrial-based economy. The process involved population migration to cities and a gradual abandonment of agricultural lands (Rudel et al., 2000; López et al., 2001; Martinuzzi et al., 2006). The last census revealed that Puerto Rico's population had decreased in the last ten years and in 2010 was estimated at 3.725 million (US Census Bureau, 2011); and that the agricultural land area (as defined by USDA) was 219,500 ha (USDA-NASS, 2011b). At present, Puerto Rico has one of the highest carrying capacities (persons/ha) compared to other areas of the world (Eswaran et al., 1999), estimated at 4.2 (based on total area, and 17 based on agricultural land area). By 2009, the gross agricultural product was 1.19% of the country's gross internal product (estimated at $\$68.84 \times 10^9$). An increase in local agricultural produce will contribute to the local economy, will partially satisfy the population's dietary needs, and will strengthen the agricultural base. The rational use of fertilizers is an important aspect of such development. The objective of this work is to examine trends in fertilizer consumption on global, regional and local scales and to describe the causes for the trends in fertilizer consumption in Puerto Rico.

MATERIALS AND METHODS

World fertilizer consumption data were gathered from the Food and Agriculture Organization (FAO) database (FAOSTAT, 2011). All data were expressed on a nutrient basis (N, P_2O_5 , and K_2O). Total fertilizer consumption was either computed as the sum of N, P_2O_5 , and K_2O or, when available, obtained directly from the database. Fertilizer consumption for Puerto Rico was gathered from DAPR (2008) and is expressed on a fertilizer basis and not on a nutrient basis, as is done by FAO. The FAO data were gathered by region and country. Regression analysis was performed on the complete or a specific time-period of the database using INFOSTAT or SigmaPlot 11.0 (Systat Software Inc., San José, CA). Trends in fertilizer consumption were established on the basis of the slope of linear regression analysis between fertilizer consumption and time. Land use data for Puerto Rico were gathered

from NASS database (USDA-NASS, 2011a) or from the FAO land use database (FAOSTAT, 2011).

Two databases for land area estimates under agricultural production in Puerto Rico are available; that published by USDA-NASS (2011a) and the other published by FAOSTAT (2011). The two estimates do not necessarily agree⁷, because of different land use classification, and different classification criteria. Furthermore, USDA-NASS has data for discrete years, whereas FAO has data for all years beginning in 1961. We have opted to use the FAO database⁸, because of its long-term continuity and because it can be used to compare Puerto Rico with other countries.

We used forages, plantains, bananas, pineapple, yam, tannier, oranges, papaya and vegetable crops to derive yield data based on crop production data and production area as reported by USDA Census (USDA-NASS, 2011b). Relative yields were computed from the ratio of yields to potential maximum yields. The potential maximum yields were obtained from expert assessment of University of Puerto Rico-Mayagüez-Agricultural Experiment Station specialists. For a selected year, fertilizer consumption per crop was obtained from commodity-specific fertilizer consumption data of PanAmerican Fertilizer Corp⁹. The fertilizer consumption of each commodity was related to that recommended by UPRM-AES and expressed on a relative percentage basis.

RESULTS AND DISCUSSION

World temporal trends. Consumption of fertilizer N, P, and K consistently increased from 1960 to 1988 and thereafter decreased until 1993 (FAOSTAT, 2011) (Figure 1). From 1993 to 2008 consumption of fertilizer N, P_2O_5 and K_2O and total fertilizer increased at annual rates of 1.65, 1.85, 2.03, and 1.76%, respectively. As of 2008, nitrogen fertilizers accounted for the biggest share (60%) of all fertilizers consumed, followed by phosphate and potash fertilizers. Agriculture's emphasis on nitrogen fertilizers has contributed to agro-ecosystem imbalances

⁷The land area defined as Land in farms by NASS is 16% greater than that defined as total agricultural land area by FAO.

⁸FAO establishes four land use categories: (1) Agricultural area, (2) Arable land and permanent crops, (3) Arable land, and (4) Permanent meadows and pastures. Agricultural area is the sum of categories 2, 3 and 4.

⁹Trade names or company names in this publication are used only to provide specific information. Mention of trade name or company name does not constitute endorsement by the Agricultural Experiment Station of the University of Puerto Rico, nor is this a mention of preference over other equipment, materials or companies.

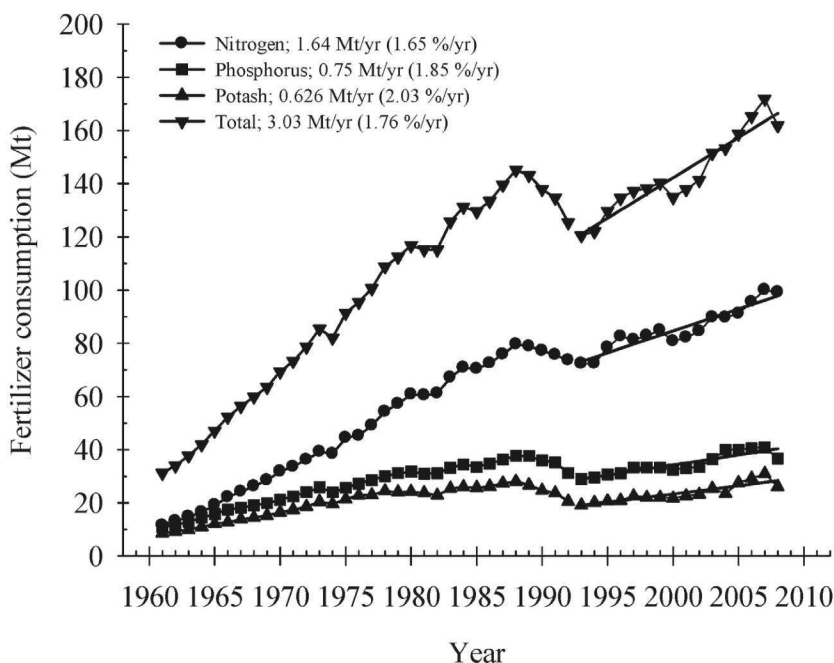


FIGURE 1. Historical trends in global fertilizer-nutrient consumption up to 2008 (FAOSTAT, 2011). Regression lines are the positive rates of increase for the time period from 1993 to 2008.

with some areas receiving excess N and others having soil K depletion (Vitousek et al., 2009; Barbazán et al., 2009; Fixen et al., 2010). The global fertilizer consumption in 2008 was 161.8 Mt¹⁰ of fertilizer, divided as 99.2, 36.6, and 26.0 Mt for N, P₂O₅ and K₂O, respectively.

Fertilizer consumption by region from 1991 to 2008. Fertilizer consumption in America and Asia increased from 1991 to 2008, whereas fertilizer consumption in Europe decreased sharply from 1990 to 1994, and remained stable up to 2008 (Figure 2A). Fertilizer consumption in Oceania increased from 1990 to 2005, and thereafter decreased for three consecutive years. Fertilizer consumption rates have not changed (there is a non-significant slope, P > 0.05, in the regression) in North- and Central America (Figure 2B). From 1990 to 2008, fertilizer consumption in South America increased at a rate of 620,000 t/yr and in the Caribbean has decreased at a rate of 25,686 t/yr (Figure 2C).

¹⁰t is tonne = Mg (megagram) = 1,000 kg

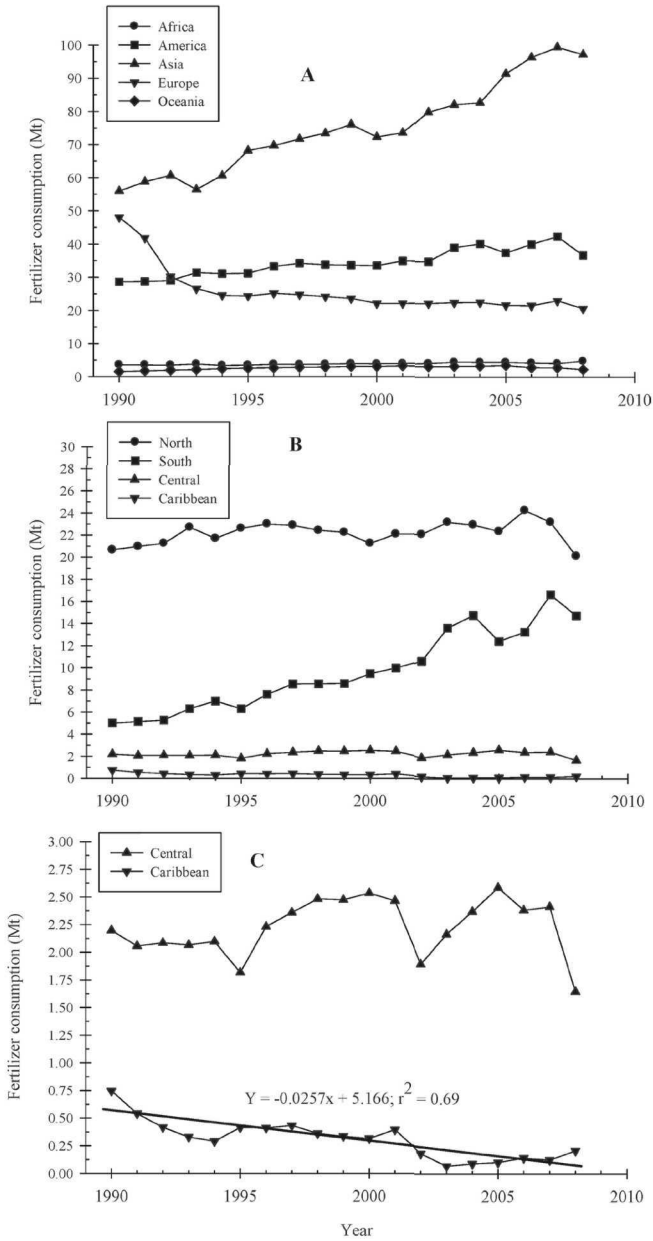


FIGURE 2. Historical fertilizer consumption from 1990 to 2008 for (A) world regions, (B) the Americas, and (C) Caribbean and Central America (FAO, 2011).

As of 2008, the biggest share of fertilizer consumption occurred in Asia with 97.3 Mt or 60.1% of the total world consumption. India and China were the largest consumers of fertilizer in Asia with 50.8 and 24.3 Mt, respectively, accounting for 31.5 and 15% of the total world consumption. America was the second region in world fertilizer consumption with 36.7 Mt, accounting for 22.7% of the global total. Fertilizer consumption in Europe was 20.7 Mt or 12.8% of the global total. Africa and Oceania were the lowest fertilizer consumers. As of 2008, the top ten fertilizer consuming countries of the world were (in order of consumption): China, India, United States, Brazil, Indonesia, Pakistan, France, Canada, Poland, and Egypt (FAOSTAT, 2011).

In America, the United States and Brazil were the largest consumers of fertilizers with 17.6 and 10.1 Mt or 10.9 and 6.5% of the global total, respectively (Table 1). Other relatively high fertilizer consuming countries in America were Canada, Argentina, Mexico, Colombia, and Chile. Fertilizer consumption in the remaining countries was less than 0.2% of the global total.

The amount of total fertilizer consumed in the Caribbean as listed for the whole region was 208,596 t or 0.13% of the total fertilizer world consumption. In contrast, when total fertilizer consumption for all Caribbean countries was accounted for individually, a total of 301,800 t was calculated. The discrepancy may be due to the fact that country-specific statistics for the Dominican Republic were not available; therefore, for that country we used 2002 consumption data. The 301,800 t fertilizer consumption for the Caribbean (excluding Guyana and Suriname), accounts for 0.82 and 0.19% of that consumed in America and in the world, respectively. Cuba and the Dominican Republic consumed about 77% of that consumed in the Caribbean, with the remaining 83,600 t being distributed among the other Caribbean islands. Fertilizer consumption statistics for Puerto Rico do not appear in the FAO database, and are therefore not included in the above analysis.

Current world fertilizer trends from 2008 to 2012. The Food and Agriculture Organization (FAO, 2008) has estimated that world fertilizer demand for N, P, and K is expected to be at 2.5, 2.8, and 2.7%/yr, respectively, through 2012. Global fertilizer consumption is projected to grow at 2.7%/yr from 2008 to 2012. Eastern Europe, Asia, Latin America and Africa will have annual growth exceeding 3%. Central Europe, North America and Oceania will have annual growth at less than 2%/yr. North America fertilizer consumption will grow at about 1%/yr. The region will increasingly need to rely on N fertilizer imports because of lower nitrogen fertilizer production and higher consumption (Huang, 2007). As of 2006 North America's share of fertilizer consumption was 15.5% and was expected to decline to 13% by 2012 (FAO, 2008).

TABLE 1.—*Fertilizer-nutrient (N+P₂O₅+K₂O) consumption in countries of America in 2008 (FAOSTAT, 2011).*

Region	Country	Fertilizer Consumption (t)	% of world total
North America	United States of America	17,600,000	10.9
	Canada	2,600,000	1.6
	Mexico	1,100,000	0.7
Central America	Costa Rica	141,500	0.1
	Guatemala	121,900	0.1
	Honduras	109,700	0.1
	El Salvador	81,100	0.1
	Nicaragua	61,300	0.0
	Panama	19,300	0.0
	Belize	3,500	0.0
South America	Brazil	10,100,000	6.2
	Argentina	1,200,000	0.8
	Colombia	901,100	0.6
	Chile	744,900	0.5
	Venezuela (Bolivarian Republic of)	628,800	0.4
	Peru	297,700	0.2
	Paraguay	280,700	0.2
	Ecuador	264,700	0.2
	Guyana	23,900	<0.1
	Bolivia	19,600	<0.1
	Guyana	23,900	<0.1
	Suriname	25,800	<0.1
	Uruguay	194,096	0.12
Caribbean	Antigua and Barbuda	13	<0.1
	Barbados	1,800	<0.1
	Dominica	222	<0.1
	Jamaica	6,400	<0.1
	Saint Kitts and Nevis	53	<0.1
	Trinidad and Tobago	58,400	<0.1
	Bahamas	ND ¹	
	Cuba	141,700	<0.1
	Dominican Republic	89,700 ²	<0.1
	Grenada	ND	
	St. Lucia	ND	
	Haiti	ND	
	St Vincent and Grenadines	ND	

¹ – ND, no data is available² – Statistics for the Dominican Republic are 2002 estimates.

The total fertilizer consumption in Latin America is projected to increase by 3.5%/yr from 2008 to 2012. Latin America's share of the global fertilizer consumption is expected to reach 10.7%. Total fertilizer consumption in west and south Asia is expected to be at 3.5 and 4.0%/yr, respectively. The two regions combined are expected to account for about 20.2% of the global fertilizer consumption. Because East Asia is the largest fertilizer-consuming region of the world, any related fertilizer development in this part of the world is expected to affect the dynamics of global fertilizer demand and supply. Total fertilizer consumption in the region is expected to be at 2.7%/yr from 2008 to 2012 and will account for 39% of the total global fertilizer consumption (FAO, 2008).

Fertilizer consumption trends in Puerto Rico: In 1962 in Puerto Rico, 232,952 t¹¹ (256,273 tons) of fertilizer (total material, not in nutrient form) were consumed (Figure 3). Samuels (1957) reported 1950 to 1953 mean consumption of 268,141 t. In 2008, the consumption of fertilizer had dropped to 16% of that in 1962 to 34,494 t (37,947 tons). It is not clear why there occurred a sharp drop in reported fertilizer consumption from 1966 to 1969. It is apparent from the above mentioned statistics that whereas fertilizer consumption on a global scale has increased, and fertilizer consumption in most countries has either increased or remained unchanged, fertilizer consumption in Puerto Rico has been decreasing in the last 40 years. Excluding four data years (1966 to 1969), a modified single exponential decay model was chosen to describe the decreasing trend in fertilizer consumption from 1966 to 1989. In fact, from 1990 (the time coincident with the closing of most of the sugar mills) to 2008, fertilizer consumption in Puerto Rico has been decreasing at a linear rate ($P < 0.05$) of -2,740 t/yr (-3,189 ton/yr) (or a -3.77% annual decrease).

The proportion of total fertilizers sold in blended form (sold as mixed formulation) in 1962 was 87%, and 89% in 2002. Over the same time period a mean value of 90% (± 2) (95% confidence interval in parenthesis) has been maintained in spite of the fact that worldwide the use of formulations has been declining, and more nutrients are being managed as individual fertilizers than in blended form. For example, in the USA the proportion of multiple nutrient materials (or blends) was 63% in 1960, and in 2007 it was 34% (USDA-ERS, 2011).

About 33% of the land area in Puerto Rico is dominated by highly weathered Oxisols and Ultisols (Beinroth et al., 2003), soils which can

¹¹Fertilizer consumption in Puerto Rico is expressed on an English short ton basis (1 ton = 2,000 lb = 909 kg = 0.909 t), of total fertilizer and not total nutrients (N+P₂O₅+K₂O) as is reported in FAO (2011) database for other countries.

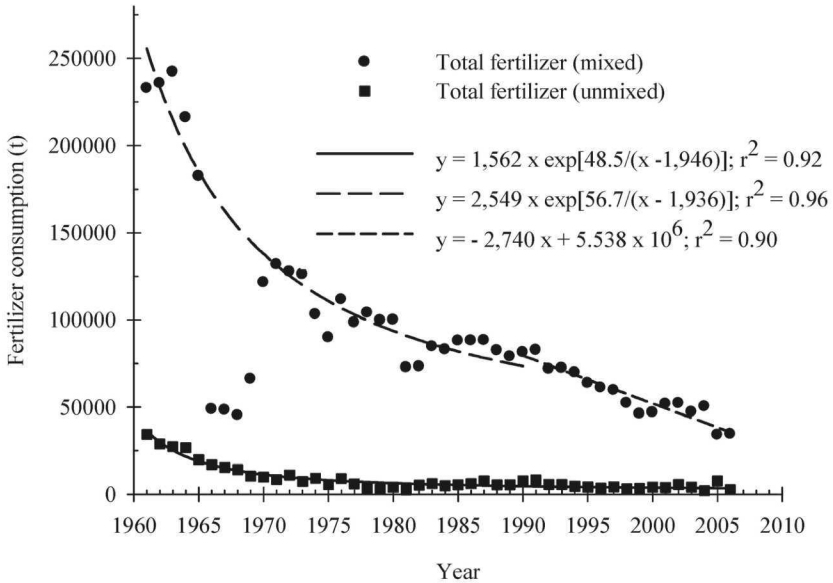


FIGURE 3. Historical trends in total fertilizer consumption (t) in Puerto Rico, expressed as single formulation blends (mixed) and individual fertilizers (unmixed) (DAPR, 2006).

sustain high agricultural productivity when managed adequately but which have limited nutrient reserves for crop growth. Crop response to N and P has been shown to occur in many of these soils (Grove, 1979; Lathwell, 1979), yet research has shown that historical applications of fertilizer-P will create soils that are not responsive to P fertilization because of soil P accumulation and subsequent release to crops (Lathwell, 1979; CAST, 2000; Syers et al., 2008). Research developed by the University of Puerto Rico Agricultural Experiment Station has demonstrated the positive effects of the use of complete fertilization for intensive crop production in highly weathered soils, as evidenced by many published articles (See for example Vicente-Chandler et al., 1983; Irizarry et al., 1981; Irizarry and Rivera, 1985). Yet, improved diagnostic tools (such as soil testing, foliar analysis, and the use of nutrient budgeting) for P and K sufficiency has reduced the need to use complete formulations in some agricultural production systems worldwide, especially in soils and farming systems with a history of manure application or long-term fertilizer application in which P and K reserves have been built up (Cox, 1992; Dodd and Mallarino, 2005;

Syers et al., 2008; IPNI, 2011). There is large potential for the use of single-nutrient soluble fertilizers, especially in areas of Puerto Rico that have drip-irrigation system infrastructure in which nutrients can be delivered individually via ferti-irrigation or in which soil testing has shown that soil P and K are above critical limits (Sotomayor-Ramírez and Martínez, 2006; Sotomayor-Ramírez, 2010). Key questions arise regarding the trends in fertilizer consumption in Puerto Rico: Is it due to the reduction in land area, or lower rates of application to the existing land area? How important is the fertilizer price in influencing farmers' application rates to crops?

Fertilizer consumption in Puerto Rico and its relation to land area. The total agricultural land area (as defined by arable land, permanent crops, and permanent meadows and pastures) in Puerto Rico has historically been decreasing (Figure 4). Linear regression analysis for the time period between 1991 and 2008 shows that the rate of agricultural land area reduction was 11,155 ha/yr. As of 2006 the agricultural land area was estimated at 201,000 ha and in 2008 at 187,000 ha. The land area under actual agricultural production (arable land and permanent crops) appears to have remained steady or actu-

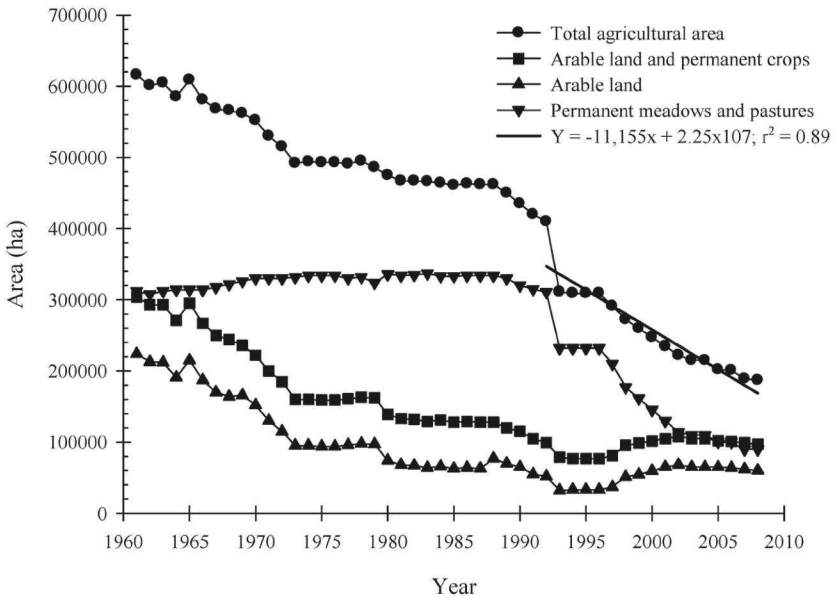


FIGURE 4. Trends in agricultural area distributed among land use in Puerto Rico from 1960 to 2008 (based on data by FAOSTAT, 2011).

ally increased from 1991 to 2008, when an estimate of 97,000 ha was reported. Historically the largest proportion of agricultural land area was dedicated to sugarcane, which in the 1950s was nearly 140,000 ha (or 48% of the total cropland) (Samuels, 1957). In 1957, 78% of the total fertilizer consumption in Puerto Rico was used in sugarcane. Although agricultural production has historically been impacted by natural phenomena, the passing of Hurricane Hugo in 1989 contributed to the elimination of a large part of the associated infrastructure of an already decadent industry. By 1990 only four mills remained with a sugarcane production area of 18,400 ha, and in 1997 the two remaining mills occupied only 4,949 ha. As sugarcane production fields were abandoned some were planted to alternate crops but the majority reverted to permanent meadows, pastures and secondary forests.

We hypothesized that the observed decrease in fertilizer consumption was primarily related to the loss of agricultural land area. Linear regression analysis between agricultural land area and fertilizer consumption between 1961 and 2006 shows that for every unit decrease in arable land and permanent crops of 1 ha, fertilizer consumption decreased by 0.781 t (Figure 5). Similar trends were observed when relating fertilizer consumption with total agricultural area for the time periods 1961 to 1992 and from 1993 to 2006. Statistics for fertilizer consumption per unit land area are not available for Puerto Rico. Thus, if we assume that all of the land area classified as arable land and permanent crops received fertilizer, and that 20% of what is classified as permanent pastures was fertilized (USDA-NASS, 2011a), an estimate of fertilizer application rate to the crop production area in Puerto Rico can be made (Figure 6). From 1961 to 2006, there was a linear decreasing trend in the fertilizer application rate of -4.6 kg fertilizer/ha/yr; for 2006, we estimate that 0.36 t/ha of total fertilizer was applied to agricultural land and part of permanent pastures areas. Although both factors (loss of agricultural land and decrease in the rate of application) are strongly correlated with fertilizer consumption and thus may be important reasons for the decreasing trends in fertilizer consumption, addition of the fertilizer rate variable to the multiple regression model between fertilizer consumption and agricultural land did not significantly improve the regression coefficient. Assuming that most fertilizer mixtures sold in Puerto Rico contain about 30% nutrients ($N+P_2O_5+K_2O$) (G. Lozada, personal communication), a nutrient rate application estimate of about 44, 15, and 29 kg/ha of N, P_2O_5 , and K_2O , respectively, was applied in 2006 to commercial cropland and managed pastures. We expect that some commodities, specifically those that have a high return on the fertilizer investment such as vegetables, plantains, and bananas will have greater application rates whereas the opposite will occur for low-valued crops

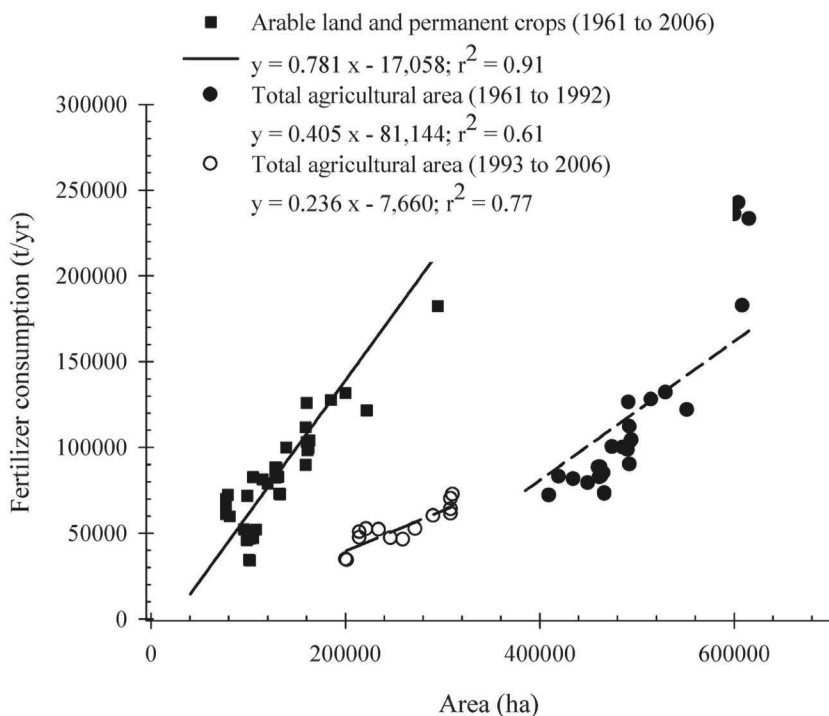


FIGURE 5. Relationship between land-use and fertilizer consumption from 1960 to 2006 in Puerto Rico.

such as haylage and coffee. There is evidence to suggest that farmers are not utilizing diagnostic tools such as soil and plant tissue testing that will guide farmers in making decisions as to whether P and K fertilizer can be reduced or eliminated.

In 2008, the crop value of coffee, plantains, bananas, and forages accounted for 88% of the total crop agricultural value in Puerto Rico (USDA-NASS, 2011b). On the basis of published information and expert assessment, crop yields for the majority of crops analyzed are below what is considered an acceptable attainable yield (Figure 7). Excluding bananas, which have relative yields of 88%, the rest of the commodities evaluated were producing well below their potential, with relative yields ranging from 24% in coffee to 64% in oranges. Considerable uncertainty may exist with regard to these estimates because site-specific historical information is not gathered, and we do not take into account differences due to varieties or other management factors influencing

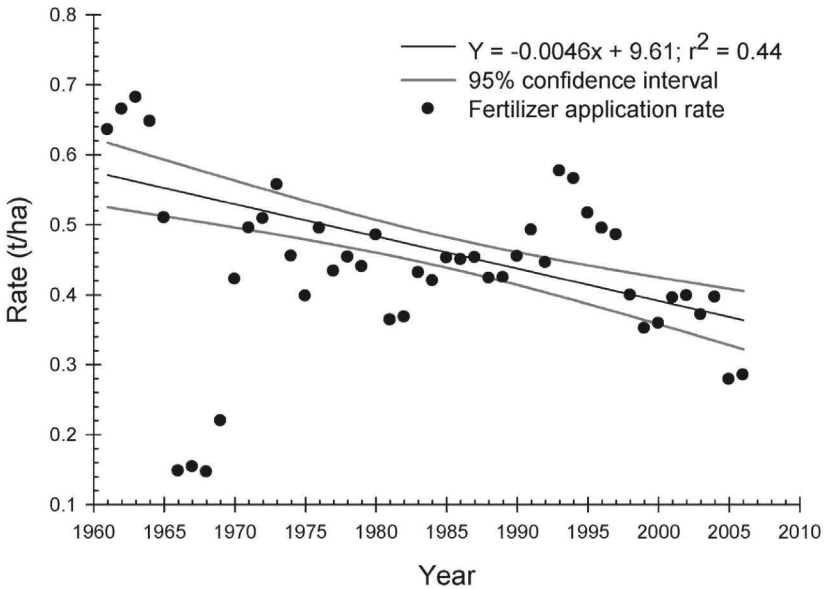


FIGURE 6. Trends in fertilizer application rate to agricultural land area and permanent crops and 20% of that area in permanent pastures in Puerto Rico. Data from 1966 to 1969 were not included in the analysis.

yields. Nevertheless, the summarized data suggests that much of the agricultural production (measured in terms of yields) on the island is below what it should be, given the technology, information and resources that are available. A recent survey by Sotomayor-Ramírez and Pérez-Alegría (2012) revealed that coffee yields (parchment coffee) in the Loco-Luchetti watershed during 2011 was 400 kg/ha and nutrient ($N + P_2O_5 + K_2O$) consumption rate was 180 kg/ha (less than half of recommended rates). In terms of fertilizer consumption, estimates for specific commodities such as vegetable crops, yams and bananas, all were above 80%. Vegetable crops and bananas are known as high-value crops because of their high market price value and they tend to have high crop:fertilizer price ratios. At high product selling price, fertilizer price fluctuation is not as important a factor influencing farmers on the rates of fertilizer levels applied to crops. In contrast, crops such as forages used for haylage and coffee have a narrow crop:fertilizer price ratio which may influence farmer fertilizer application rates. Our preliminary analysis suggests that most commodities are not being fer-

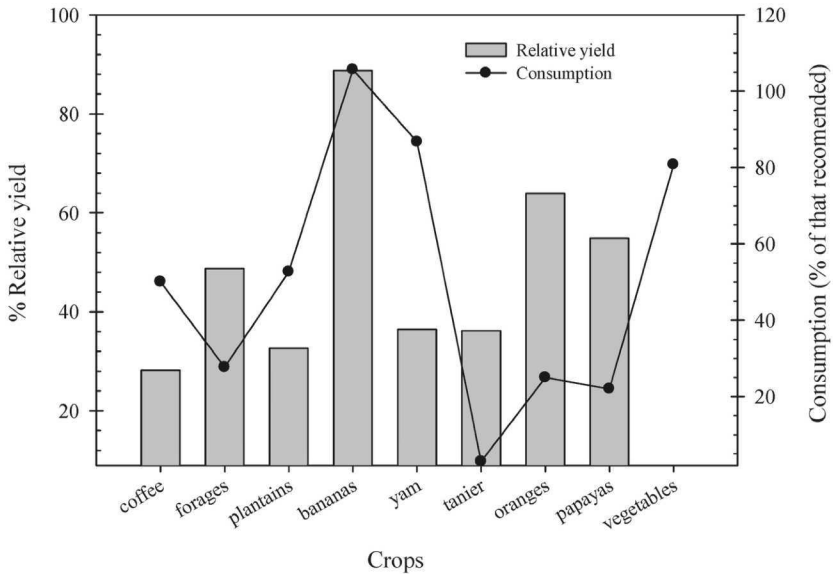


FIGURE 7. Crop yields for selected commodities in relation to estimated fertilizer application rates. Relative yield for vegetables cannot be computed because of the high variation of reported yields for different crops.

tilized adequately. The mean annual fertilizer-nutrient consumption for forage in the Lajas Valley Agricultural Reserve for the years 2000 through 2010 was 6 kg/ha (Sotomayor-Ramírez and Pérez-Alegría, 2012).

Crop yield estimates for Puerto Rico may be related to fertilizer consumption rates. The FAO reports a nutrient fertilizer ($N+P_2O_5+K_2O$) consumption rate in Puerto Rico of 92 kg/ha (FAOSTAT, 2011); our nutrient fertilizer consumption estimate is 88 kg/ha (or a 4% difference). This estimate contrasts with 1957 estimates in which about 350 kg/ha of fertilizer-nutrients (sum of N, P_2O_5 , and K_2O) was applied to sugarcane cropland (Samuels, 1957). In 1994-95, the nutrient fertilizer consumption rate in the world was 88 kg/ha, 90 kg/ha in North America, 216 kg/ha in East Asia, 77 kg/ha in South Asia, 10 kg/ha in Sub-Saharan Africa, and 65 kg/ha in LatinAmerica (Bumb and Baanante, 1996). Fertilizer consumption rate has intensified throughout the world as the 2008 averages were 129 kg/ha for the world, 146 kg/ha in Latin America and the Caribbean, 157 kg/ha in North America, and 188 kg/ha in European Union countries. Current fertilizer consump-

tion rate estimates for Puerto Rico are well below those for the world, Latin America and the Caribbean, North America, and European Union countries. Fertilizer consumption rate in Puerto Rico is ranked 72 among 149 countries that have reported fertilizer consumption statistics (FAOSTAT, 2011).

CONCLUSIONS

Fertilizer consumption in Puerto Rico has been decreasing and is now at a historical all-time low. The factors causing the decrease in consumption are to a major extent the decrease in agricultural land area and, to a minor extent, the decrease in fertilizer rate application. Knowledge of these fertilizer consumption trends in Puerto Rico and a comparison with those occurring in other regions will help to create awareness related to adequate fertilizer management, all of which will lead to a more sustainable agricultural production. Management of fertilizer-P and -K can be modified in relation to recommended rates only if diagnostic tools such as soil and plant tissue testing are used as guides. The results in this paper demonstrate that the decrease in fertilizer consumption in Puerto Rico is related to the decrease in agricultural land area all of which may contribute to the gradual loss in competitiveness of the Island's agricultural sector.

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