CARIBBEAN FOOD CROPS SOCIETY

40

Fortieth

Annual Meeting 2004

Proceedings of the Caribbean Food Crops Society. 40:198-209. 2004

RELEVANT INVASIVE SPECIES FOR THE AGRICULTURAL SECTOR IN PUERTO RICO: IDENTIFICATION OF THE PROBABLE ECONOMIC IMPACT

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ABSTRACT: The Agricultural Sector in Puerto Rico from 1998 to 2002 reported an annual mean Gross Agricultural Income (GAI) at farm level of $718.9 million. During this six-year period the livestock and crop commodities generated a mean gross income of $390.1 and $231.0 million, respectively. Dairy production was the most important commodity; it generated an annual mean gross income of $193.7 million, 26.9% of the total GAI. The principal crops and their mean gross income in millions were: plantain, $48.6; coffee, $38.4; ornamentals, $33.5; bananas, $13.3; and mango, $12.8. Besides their economic contribution, coffee, plantain, and bananas have a social and environmental importance because the production areas are located mostly in the central mountain region in Puerto Rico. The agricultural sector is the major source of income and employment in the central mountain area. In this area rise the rivers and lakes utilized as water sources for human and agricultural consumption. The established invasive species, or the ones with establishment potential, that could impact economically the principal agricultural commodities were identified. The invasive species at a pre-entry level identified for the crop commodities are coffee berry borer (*Hypothenemus hampei*); black sigatoka for plantain and banana (*Mycosphaerella fijiensis*); and the mango seed weevil (*Sternochetus mangiferae).* The established invasive species identified for dairy production are the Johnei Disease causal agent (*Mycobacterium avium paratuberculosis*) and the parasite tick (*Boophilus microplus).* This study will emphasize the crop invasive species. The economic impact of the invasive species on the agricultural sector was classified as direct impact to the commodity, the market, and the trade; as indirect impact on the environment, health, and other economic sectors.

Key words: Invasive species, Economic impact analysis, Coffee berry borer (*Hypothenemus hampei*), Plantain black sigatoka (*Mycosphaerella fijiensis)*, Mango seed weevil (*Sternochetus mangiferae).*

ESPECIES INVASORAS RELEVANTES PARA EL SECTOR AGRÍCOLA DE PUERTO RICO: IDENTIFICACIÓN DEL POSIBLE IMPACTO ECONÓMICO

RESUMEN: El sector agrícola de Puerto Rico del 1998 al 2002 reportó un Ingreso Bruto Agrícola Medio (IBAM) total a nivel de la finca de $718.9 millones. Durante estos seis años las empresas de animales y subproductos y la de cosechas generaron un IBAM de $390.1 y de $231.0 millones, respectivamente. La empresa de mayor importancia en la agricultura de Puerto Rico es la producción de leche, la cual ha generado un IBAM de $193.7 millones, 26.9% del ingreso total de la agricultura. Las cosechas principales y su IBAM en millones son plátano ($48.6); café ($38.4); ornamentales ($33.5); guineo ($13.3) y mango ($12.8). Además de su aportación económica las cosechas de café, plátano y guineo tienen una importancia social y ambiental, ya que la mayor parte de su producción se sitúa en la zona central montañosa de la

isla. El sector agrícola es la fuente principal de empleos en la zona montañosa y allí nacen los afluentes que proveen agua para el consumo humano y agrícola. Se identificaron especies invasoras establecidas o con potencial de establecerse, que podrían impactar económicamente las principales empresas agrícolas. Las especies invasoras identificadas para las cosechas fueron la broca de café (*Hypothenemus hampei*), la sigatoka negra en plátanos y guineos (*Mycosphaerella fijiensis*) y el picudo de la semilla del mango (*Sternochetus mangiferae).* Las especies invasoras identificadas para la empresa de ganadería de leche fueron la enfermedad de Johnei (*Mycobacterium avium paratuberculosis*) y la garrapata (*Boophilus microplus).* Este estudio enfatizará en las especies invasores con potencial de establecimiento en las cosechas. El impacto económico de las especies invasoras sobre el sector agrícola fue clasificado en posible impacto directo a la empresa, al mercado y a la comercialización, e impacto indirecto al ambiente, a la salud y a otros sectores económicos.

INTRODUCTION

The Agricultural Sector in Puerto Rico from 1998 to 2002 reported an annual mean Gross Agricultural Income (GAI) at farm level of $718.9 million (Departmento de Agricultura –PR, 2003, 2001, and 1999). During this six year period livestock and crop commodities generated a mean gross income of $390.1 (54.3%) and $231.0 (32.1%) million, respectively. Dairy production was the most important commodity; it generated an annual mean gross income of $193.7 million, 26.9% of the total GAI. The principal crops and their mean gross income in millions were plantain, $48.6; coffee, $38.4; ornamentals, $33.5; bananas, $13.3, and mango $12.8. The percentage contribution of the principal crops to the mean crop gross income was plantain, 21.0%; coffee, 16.6%; ornamentals, 14.5%; banana, 5.7%; and mango, 5.5%.

The total cropland in Puerto Rico is 533,081.0 "cuerdas" (213,232.4 ha), and the total number of cropland farms is 19,030 (USDA, 2000). Coffee is planted on 14.5% of the total cropland and is cultivated on 55.8% of the total farms. Plantains occupy 14.5% of the cropland and are cultivated on 39.1% of the farms. Bananas are planted on 2.3% of the cropland and are cultivated on 21.6% of the farms. Mangos represent 0.5% of the cropland and are cultivated on 1.3% of the farms. Ornamental plants occupy 0.06% of the cropland and are cultivated on 1.2% farms. The Agricultural Census in 1998 reported the existence of 1,932 farms in dairy production; however, for the same year the Dairy Industry reported 403 commercial dairy farms in operation (Cortés, 2004).

Coffee, plantain and banana production areas are located mainly in the mountain region. However, plantains and bananas are cultivated throughout the island. In the central mountain regions they are intercropped with coffee. The principal coffee production area is located in the west-central mountain chain called "Cordillera Central." The agricultural sector is the major source of income and employment in the central mountain zone. In this area originate the rivers and lakes utilized as water sources for human and agricultural consumption in Puerto Rico. About 250,000 inhabitants in eight municipalities of the mountain region depend directly or indirectly on the coffee commodity (Alamo, 2002). Plantain and coffee are part of Puerto Ricans cultural diet. The commercial mango production area is on the south coast plains; about 80.0% of the production is exported to Europe and to the USA. Ornamentals are grown across the island, frequently in the east central mountains. The dairy farms are concentrated on the north plains of the island.

In fiscal year 2001, Puerto Rico imported $2,142.6 million in food. In the same year $66.6 million in agricultural products was exported (Junta de Planificación, 2001). The principal agricultural products exported were mango, tomato and coffee. About 80% of mango production was exported to Europe and USA market. Historically tomatoes producers exported 60% of local production to USA market. About 6% of the coffee production was exported mostly to the specialty coffee market in USA.

There is a pre-entry quarantine in Puerto Rico for the import of plantain to avoid the entrance of the black sigatoka and the moko disease (*Ralstonia solanacearum*). The imports of green coffee to the island have a pre-entry quarantine because of the coffee berry borer.

The island's strategic geographic position and the consumer's acquisitive value allow active trade. The tourism activity in fiscal year 2001 attracted 4.9 million visitors, who spent $2,728.1 million on the island. (Junta de Planificación 2002). There is one international airport in Puerto Rico (Luis Muñoz Marín) plus six smaller air fields across the island. The main sea ports are located in San Juan, Ponce, Mayaguez, and Aguadilla. There is much cruiser activity, ships departing weekly from the port in San Juan to the Lesser Antilles. In the eastern part of the island there are three ports that handle human and trade transportation from the main island to the islands of Vieques and Culebra. The private vessel traffic in Puerto Rico departs principally from private marinas located in the east (Fajardo), the north (San Juan), the south (Ponce-Salinas) and the west (Lajas-Cabo Rojo). Illegal human trade traffic is reported in the west part of the island coming mostly from the Dominican Republic. This active legal and illegal trade, especially in fresh agricultural commodities, increases the risk of the introduction and spread of invasive species associated with pests and diseases.

Puerto Rico is a Commonwealth of the United States of North America (USA). Due to the political relationship, the USA's international trade policy has direct impact on Puerto Rico's economic growth and development. Furthermore, there is a worldwide trend of market consolidation and the USA is part of this trade policy. The North America Free Trade Agreement (NAFTA), MERCOSUR, and CARICOM are examples of market merger efforts. Also, the Free Trade Area of the Americas (FTAA), whose principal objective is to eliminate barriers to trade and create a single market within the western hemisphere, is expected to be functioning by 2005 (Palacios, 2004).

The political and economic relationship is such that the United States Department of Agriculture (USDA) and the Department of Agriculture of Puerto Rico (DAPR) manage the control policies for invasive species. Most of all the other countries' imports are checked by these two agencies. However, the United States' imports are verified only once.

The Economic Research Service of the United States Department of Agriculture (USDA-ERS 2003) presented a 1999 Executive Order, 13112, which defines an invasive species as one that is nonnative, alien, or exotic to the ecosystem under consideration, and one whose introduction causes, or is likely to cause, economic or environmental harm or harm to human health. Besides, the definition considers costs, benefits or net damage, of an invasive species. Sometimes in some crops, ornamentals, and animal industry, the benefits of these non-native species exceed all the costs involved in controlling their entry or their damage once established.

The rate of introduction of invasive species in Puerto Rico is evident in the results, reported Serrano et al., (2001). They reported that between 1963 and 1999 one to six exotic insects were introduced per year, an average of 1.4 major insect pest species. Most of these introductions came from Caribbean Countries, Central and South America and the United States.

The majority of the interceptions made at the Luis Muñoz Marín International Airport came from the Dominican Republic, Colombia, Costa Rica, Antigua, Barbados, Dominica and Grenada.

The economic impact of those pests and diseases must be estimated, considering market, non market and environmental damages. The Council for Agricultural Science and Technology (CAST), in a 2002 paper, expressed that if non-native species become pests, the economic risks include lost production, diminished quality, increased production costs, decreased flexibility in production/management decisions, and increased risks for human health. Evans (2002), remarked that the research agenda on invasive species has been developed by biological science researchers, and much of the previous "economic" research on invasive species has been conducted by non-economists. As such, the economic analysis suffers either from various methodological problems (e.g., incorrect economic valuation, ignoring non market environmental damages) or from being peripheral to the biological study.

A limitation for the economic impact analysis is that there are several different institutions collecting information regarding pest interception, introduction, spread and control. Although there is a collaboration accord among institutions, the information collected by them is not compiled in a coordinated manner, hence one of the difficulties in assessing what the economic impact could be on the sector if a given pest or disease were introduced.

Although in Puerto Rico there is a great amount of biological data on physiological behavior of pests and diseases, and records of intervention, introduction, and surveillance, this information is unevenly diffused across agencies, scientists and producers (Alamo, 2004). It is necessary to compile the information in such a way as to facilitate exchange of data and experience among groups. A link between crop protection scientists, regulatory plant protection agencies and economists is needed. The groups need to develop a guideline for asking questions that facilitate the gathering and compilation of data for economic impact analysis.

In April 2003, a proposal titled Economics of Managing Invasive Species in Tropical and Subtropical Areas in the United States of America was approved by T-STAR initiative (VanSickle et al., 2003). This proposal includes the regions of Florida USA, Hawaii, Guam and Puerto Rico. The overall objective of this project is to provide decision makers and regulatory authorities with new resources for decisions involving invasive species management programs, including pre-entry quarantine measures and management of established pests. Within this broad objective, there are two specific objectives of the project: development of a comprehensive invasive species risk management framework that incorporates the economic impacts of invasive species; and development of a collaborative interdisciplinary network of institutions and persons involved with invasive species management.

As part of these objectives, a number of case studies will be done in regard to particular invasive species problems in the collaborating regions. The case studies are a key part of the project (Bigsby et al., 2003). They will:

- Provide the basis for studying important regional invasive pest problems.
- Develop applications of economics to the management of invasive species.
- Provide an initial database for the risk management framework being developed in the project, all of which will be available for future studies of invasive species.
- Provide the basis of collaborative networks for invasive species management.

The study presented in this paper pretends to identify priorities and select the relevant invasive species problems that will be analyzed in the case studies for Puerto Rico. The identification of the possible economic impact, direct or indirect as well as market and no

market, will be established for the selected invasive species. The methodology approach for measuring the economic impact is identified.

OBJECTIVES

1. To initiate the interdisciplinary group link among crop protection scientists, regulatory federal and local protection agencies, and economists.
2. To identify and select the important pest problems and characterization of the pest and its effects on the agriculture of Puerto Rico.
3. To identify the possible economic impact, direct or indirect as well as market and no market, for the selected invasive species case studies.

METHODOLOGY

The methodology utilized in this study is part of the background paper prepared and circulated by the participating researchers of the project "Economics of Managing Invasive Species in Tropical and Subtropical Areas in the United States of America" (Bigsby et al., 2003). In order to ensure coordination of the project, the development of the case studies will follow this process:

- Preparation and circulation of a background paper on pest risk analysis outlining the types of information that will be required from the case studies.
- Initial identification of important pest problems and characterization of the pest and its effects in the participating regions. Using the background paper, collaborators will identify cases that are important to their particular regions.
- Convening of a workshop to present and discuss potential case studies and provide feedback for the development of the conceptual framework and model.
- Confirmation of case studies.
- Conducting case studies

The background paper on pest risk analysis will outline the types of information required from the case studies. The paper will provide the methodology for the identification and categorization of the possible economic impact.

For the purpose of pest risk assessment, economic effects can be categorized as direct and indirect pest effects, and as market and non-market effects. The direct and indirect categories refer to the way in which the effects of a pest are manifested, and in turn, point to the way in which the effects might be measured. Direct pest effect concentrates on direct impacts of a pest on a host species, and covers host-specific impacts such as yield loss or mortality. It can include a range of hosts such as agricultural and horticultural crops, pasture plants, forests, and controlled or wild environments. Indirect pest effects cover non-host specific impact. These are economically relevant effects that are not directly linked to the effect the pest has on its host. Indirect effects which are created by the presence of the pest, but not specific to the pest-host dynamic, include public health issues, restrictions on traffic flow, key ecosystem function compromised, research requirements, market access problems and tourism. An indirect impact is generally a value that is not tied directly to an area or volume that has been infested as with the direct impact (Bigsby et al., 2003).

Market effects refer to those effects for which the market provides an evaluation of the benefits and costs. Such effects can easily be identified in an existing market. This means that the effects of the pest can be identified in terms of (say) quantities bought and sold, and market prices. The key factor is that there is a market price and that quantities affected can be easily identified and measured (e.g. $/ton, acres, or volume). Market effects include a range of changes in producer costs and returns, such as direct producer costs, input demands or output, and change in product quality. Market price covers the full range of activities from farmers to processors and exporters. Market effects also cover peripheral changes such as that of market access, where there might be changes in quarantine measures in export markets. Wider economic change might arise from a significant effect such as the loss of a domestic agricultural or tourist sector, which would cause unemployment, and changes in wages, land prices and exchange rates.

Non-market effects refer mainly to those changes for which there are no direct market evaluation. In order words, there is no information on prices, costs, profits or quantities. Examples of such impacting factors include environmental effects and loss of biodiversity. The key factor here is that there is an intuitive understanding that there is a cost being incurred, but a lack of information on what the cost might be. Consequently, a variety of techniques have been developed to measure the value of such effects, i.e., the change in consumer surplus associated with the effect.

The direct, indirect, market and non-market categories combine to form an economic impact matrix. The economic impact matrix is used to identify and classify economic effects. An effect that is economic in nature is one that causes changes to what is done, or that causes a change that is important to other activities.

The types of economic analysis that are available can be categorized according to the scope or level of economic activity that is measured. The FAO (1996) guidelines group economic analysis into partial budget, partial equilibrium, and general equilibrium.

Partial budget analysis, the narrowest in scope, deals with changes in the profits of individual producers. Partial equilibrium analysis is wider in scope than partial budget, dealing with a production sector as a whole rather than with individual producers, and can model the effects of a pest on changes in prices. Partial budget and partial equilibrium analysis can also be termed microeconomic approaches.

General equilibrium analysis is a level higher than partial equilibrium analysis, encompassing an entire economy, and allowing for the effects of a pest on wages, exchange rates and national welfare to be measured. The general equilibrium analysis is a macroeconomic approach. These types of economic analyses form a progression of analytical opportunities that are available as the scope of a potential pest impact increases.

To develop the case studies contact was made with an interdisciplinary group who participated in a workshop with the project's agricultural economics to identify the relevant invasive species problems, discuss and select the potential case studies and provide feedback for the development of the conceptual framework and model .The participants were biologists and economists, local and federal regulatory plant protection agencies, and persons involved with invasive species. Crop protection scientists of the University of Puerto Rico provided the information for pest and disease introductions, spread, hosts and damage. The "Sanidad Vegetal" Division of the Department of Agriculture of Puerto Rico and the Animal and Plant Health Inspection Service (APHIS-USDA) provided information on interceptions, surveillance and spread of the invasive species. Information was gathered in order to select the most important pests and diseases and to characterize of the pests and their effects in Puerto Rico.

The economic impact of the possible effects of the invasive species in the Puerto Rico agricultural economy was categorized as direct and indirect, as well as market and non market. The matrix of the economic impact was developed. A preliminary approach was designed to gather data on the economics and biological data to develop a comprehensive framework for species risk management.

RESULTS AND DISCUSSION

The regional interdisciplinary group composed of crop protection scientists, regulatory federal and local protection agencies, and economists had a workshop to present and discuss potential case studies and to provide feedback for the development of the conceptual framework and model. The potential invasive species discussed were coffee berry borer (*Hypothenemus hampei*), black sigatoka for plantains and banana (*Mycosphaerella fijiensis*), the mango seed weevil (*Sternochetus mangiferae),* and for dairy production the Johnei disease causal agent (*Mycobacterium avium paratuberculosis*) and the parasite tick (*Boophilus microplus).* The interdisciplinary group pre-selected Puerto Rico's invasive species for the case studies on economic impact.

Researchers of the T-STAR project from the universities of Florida, Puerto Rico, Hawaii, and Guam confirmed the following invasive species case studies: coffee berry borer, black sigatoka for plantains and banana, and the mango seed weevil. The three invasive species selected for the case studies are at a pre-entry level. The characterization of the pests and their effects on the agriculture of Puerto Rico will be discussed in the following order:

Coffee Berry Borer (*Hypothenemus hampei*)

Characterization of the pest (Biology Profile):

The coffee berry borer is a phytophagus insect. The invasion is at a pre-entry level status. It is already established in the nearby Dominican Republic. Puerto Rico has a local quarantine for green coffee with the purpose of decreasing the risk of the introduction of the berry borer.

Direct physical damage on coffee beans due to the berry borer would result in a severe infestation and a yield reduction of 30% to 80% (Franqui, 2003). Chemical control methods would impact environmentally sensitive areas. The possible pathway for the insect introduction could be illegal coffee bean imports. International travel and trade (particularly with the Dominican Republic) have increased the risk of introduction. The pest could be transported on clothes and tools, among other items. Private vessel traffic between Puerto Rico and the Dominican Republic involves a risk of introduction because of the low levels of private port inspections due to limited resources of regulatory agencies

Characterization of the Economic Impact:

The coffee commodity is relevant in socio-economic and environmental aspects. This commodity comprises 10,622 farmers and employs 10,000 workers in a region with limited economic activities and high unemployment rates. The possible yield reductions, control costs, and quality changes due to the berry borer will impact farmers' returns, thus affecting employment demand. The specialty coffee exports could be affected. The damage on the bean

due to berry borer could decrease the cup quality. Coffee is grown on steep mountain slope with high humidity. The environment will be impacted due to the combined effect of rainfall and the chemicals, used for control. The rivers and lakes in the coffee production region are a significant source of water for human consumption in Puerto Rico. Chemical control methods will possibly impact the water sources in an environmentally sensitive area. The cost of pre-invasion control management of the watch alert system will increase in government and regulatory agencies.

Table 1 shows the matrix of the economic impact of a possible introduction of the coffee berry borer. The impact matrix shows the expected market, non market under direct and indirect categories as well.

The management approach or policy options to avoid the introduction of the coffee berry borer suggest that border inspections and quarantine activities must be increased because of the active trade of fresh commodities and visitors and the proximity of the Dominican Republic to Puerto Rico. The regulatory agencies will incur costs for surveying, monitoring and other pre-entry watch alert activities. The pre-entry risk management options must be enforced by local and federal government and regulatory agencies.

Plantain Black Sigatoka (*Mycosphaerella fijiensis*)

Characterization of the pest (Biology Profile):

Black sigatoka is a pathogenic fungus at a pre-entry quarantine status. It is already established in the nearby Dominican Republic and Florida, USA. Puerto Rico has a local pre-entry quarantine for plantains with the purpose of decreasing the risk of the introduction of black sigatoka and the moko disease.

Direct physical damage on foliage and plantains due to black sigatoka introduction will cause a reduction of fruit size and quality, and plant defoliation. Severe infestation will result in a 50% to 100% yield reduction (INIFAP, 1998). International legal and illegal travel and trade (particularly from the Dominican Republic) have increased the risk of introduction. Private vessel traffic between Puerto Rico and the Dominican Republic involves a risk introduction because of the low levels of private port inspections due to limited resources of regulatory agencies. The most important vectors are legal or illegal passengers, contaminated plant material, and weather conditions (winds).

Characterization of the Economic Impact:

The plantain and banana commodities are economically the most important crops in Puerto Rico. The possible yield reductions, cost control, and quality changes due to Black Sigatoka introduction will impact farmers' returns, thus affecting the employment demand of rural areas. The aquifers in the production region are a significant source of water for human consumption in Puerto Rico. Chemical control methods would possibly impact the water sources in an environmentally sensitive area. The possible relaxation on phytosanitary measures would allow lower cost of the imported product. In this scenario local producers would face lower prices and potentially lose market share. The pre-invasion control management cost of a watch alert system will be increased in government and regulatory agencies

Table 2 shows the matrix of the economic impact of a possible introduction of Black Sigatoka. The impact matrix shows the expected market, non market under direct and indirect categories as well.

The management approach or policy options to avoid Black Sigatoka introduction suggests that border inspections and quarantine activities be increased because of the active trade of fresh commodities and visitors and the proximity of the Dominican Republic to Puerto Rico, The regulatory agencies will incur costs for surveying, monitoring and other pre-entry watch alert activities. The pre-entry risk management options must be enforced by local and federal government and regulatory agencies.

Mango Seed Weevil (*Sternochetus mangiferae)*

Characterization of the pest (Biology Profile):

The mango seed weevil (*Sternochetus mangiferae) is a* phytophagus insect at a pre-entry quarantine status. The insect is established on eastern Caribbean Islands. Direct physical damage to fruit seed, reduction in fruit size and quality are the results of the weevil attack (Franqui and Gaud, 2003).

The most important pathways or vectors are contaminated plant (seed), legal or illegal passengers, and trade. International travel and trade of fresh products have increased the risk of introduction. Tourism cruises and private vessels between Puerto Rico and infested eastern Caribbean islands (St. Lucia, Barbados, Dominica, Guadalupe, and Martinique), increase the risk of introduction. Domestic intra-island passengers in the east private and public marinas are not inspected because of the limited resources of local agencies, thus increasing the risk of introduction.

Characterization of the Economic Impact

The mango commodity is the most economically important fruit in Puerto Rico Over 80% of the local production is exported to Europe and the United State markets. Possible yield reductions, control costs, quality changes due to the mango fruit weevil will impact farmers' returns, thus affecting employment and wages. In the introduction scenario, local producers would face lower prices and potential loss of market share and loss of the export markets of the United States and Europe due to quarantine. Households' backyard trees will also be affected. The pre-invasion control management cost of the watch alert system will increase. Educational efforts will intensify in government and regulatory agencies.

Table 3 shows the matrix of the economic impact of a possible introduction of the mango seed weevil. The impact matrix shows the expected market, non market under direct and indirect categories as well.

The pre-entry risk management options must be enforced by government and regulatory agencies (local and federal). Considering the active trade of fresh commodities, the visitors on cruises, and the proximity of Puerto Rico and infested east Caribbean islands, border inspections and quarantine activities must be increased. The regulatory agencies will incur costs for surveying, monitoring and other pre-entry watch alert activities.

RESEARCH APPROACH

To gather economic data on the coffee, mango, plantain and banana commodities and biological data on coffee berry borer, mango seed weevil and black sigatoka, in order to develop a comprehensive risk management framework the following approach has been preliminary planned:

- Use of presence-absence model.
- Coordination with APHIS USDA and Department of Agriculture to survey domestic travelers on private and public vessels to determine probabilities of invasive introductions.
- Partial budget analysis (market and trade).
- Control management scenarios or options, eradication costs.
- Socio-economic and environmental damage evaluation.

CONCLUSIONS

The T-STAR project Economics of Managing Invasive Species in Tropical and Subtropical Areas in the United States includes the regions of Florida USA, Puerto Rico, Hawaii and Guam. There are two specific objectives of the project: development of a comprehensive invasive species risk management framework that incorporates the economic impacts of invasive species; and development of a collaborative interdisciplinary network of institutions and persons involved with invasive species management. As part of these objectives, a number of case studies will be done in regard to particular invasive species problems in the collaborating regions.

Puerto Rico's interdisciplinary regional group identified three relevant invasive species for the agricultural crops sector. The three invasive species selected for the case studies are: coffee berry borer (*Hypothenemus hampei*), black sigatoka for plantains and banana (*Mycosphaerella fijiensis*) and the mango seed weevil (*Sternochetus mangiferae).* The economic impact of the possible effects of the invasive species in the Puerto Rico agricultural economy was categorized as direct and indirect, as well as market and non market. The matrix of the economic impact was developed. A preliminary approach was designed to gather data on the economics and biological data to develop a comprehensive framework for species risk management.

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Table 1. Coffee Berry Borer Impact Matrix

	Market Impact	Non-Market Impact
Direct Pest Effects	Coffee products (control costs) Trade effects (specially coffee market)	Environmental (water supplies)
Indirect Pest Effects	Socio-Economics (income & employment) Pre and post entry control management	

Table 2. Black Sigatoka Impact Matrix

	Market Impact	Non-Market Impact
Direct Pest Effects	Plantain and banana (control, costs, yield and profit decrease) Trade effects (loss of local market share to imports)	Cultural (Diet)
Indirect Pest Effects	Socio-Economic (lost of income & employment) Pre-entry control management costs	Environment (chemical control affect water quality)

Table 3. Mango Seed Weevil Impact Matrix

	Market Impact	Non-Market Impact
Direct Pest Effects	Mango(control cost yield reduction) Trade effects (market access)	
Indirect Pest Effects	Pre and post entry control management cost	Environmental (chemical control)