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Cynthia Fridgen
Major professor

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A SYSTEMS METHOD FOR EVALUATING THE SUSTAINABILITY OF AG-PRODUCTION: AN EVALUATION OF BANANA PRODUCTION IN COSTA RICA

By

Carlos E. Hernández

A DISSERTATION

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Department of Resource Development

1997

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ABSTRACT

A SYSTEMS METHOD FOR EVALUATING THE SUSTAINABILITY OF AG-PRODUCTION: AN EVALUATION OF BANANA PRODUCTION IN COSTA RICA

By

Carlos E. Hernández

This dissertation proposes a method for evaluating the sustainable performance of agricultural production practices. It uses Costa Rica's banana production industry as a case to test the method. It presents an overview of banana production in Costa Rica based on the importance of bananas as an export crop and the environmental and social impacts associated with their production.

The paper takes a systems approach to define the banana production system and explicates it with a model. Cause and effect relationships are identified. The intensities of these relationships are derived using hard data when available, and expert opinion when no data exists.

A panel of experts rates the conventional production practices and the alternative production practices. A mathematical method is structured to aggregate ratings into sustainable performance indices. Best available alternative practices are recommended, based on the resulting indices. It is hoped that these recommendations will help bring about a more balanced approach to the exploitation of Costa Rica's natural and human resources.

DEDICATED

To Amalia, Gabriela and Jaime for their support and love.

To Dr. Gordon and Norma Guyer for taking us in their home.

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LIST OF TAB

LIST OF FIGU

CHAPTER 1

INTRODUCTIO

1.1 Topi
1.2 Phi
1.3 Obje
1.4 Defi
1.4.1
1.4.2
1.4.3
1.4.4
1.4.5
1.5 The
1.6 State
1.7 Justi
1.8 Cond
chang
1.9 Conc

CHAPTER 2

PROBLEM FO

2.1 Intro
2.2 Syste
2.3 Costa
2.4 Bana
2.5 Syste
2.6 Wast
2.6.1
2.6.2
2.6.3
2.6.4
2.6.5
2.7 The
Cond

TABLE OF CONTENTS

LIST OF TABLES VIII

LIST OF FIGURES X

CHAPTER 1

INTRODUCTION...1

1.1 Topic of the Dissertation..1
1.2 Philosophical and Theoretical Framework.....................................2
1.3 Objective 8
1.4 Definitions 9
1.4.1 Systems Approach 9
1.4.2 Sustainability and Sustainable Development 16
1.4.3 Agroecology 28
1.4.4 Ecological Engineering...31
1.4.5 Monitoring Sustainability 33
1.5 The researchable questions, problem and search for solutions 43
1.6 Statement of hypothesis..46
1.7 Justification and relevance 47
1.8 Conditions outside the control of the producers that have a bearing on change 53
1.9 Conclusion 55

CHAPTER 2

PROBLEM FOCUSED LITERATURE REVIEW..57

2.1 Introduction 57
2.2 Systems Approach 59
2.3 Costa Rica...61
2.4 Banana Production in Costa Rica 63
2.5 Systems Analysis of Banana Production..66
2.6 Wastes and Alternatives..76
2.6.1 Nonpoint Source Residuals..76
2.6.2 Point Source Degradable Wastes 85
2.6.3 Point Source Liquid Waste 86
2.6.4 Point Source Nondegradable Waste 88
2.6.5 Hazardous Waste - Agrochemical Containers...........................91
2.7 The Challenge..93
Conclusion 94

CHAPTER 3

METHODS.....
3.1 Introd
3.2 Prob
3.2.1
3.2.2
3.2.3
3.2.4
3.3 Partic
3.4 Instru
3.4.1
3.4.2
3.4.3
3.5 Proce
3.5.1
3.5.2
3.6 Statis
Limit
Conc

CHAPTER 4

RESULTS.....
4.1 Introd
4.2 Pane
4.3 Con
4.4 Alter
4.5 Crite
4.6 Rela
4.7 Rat
4.8 Def
4.9 Sust
4.10 Hypo

CHAPTER V

FINDINGS, C
5.1 Intro
5.2 Prob
5.3 Rese
5.4 Find
5.4.1
5.4.2

CHAPTER 3

METHODS **97**

3.1 Introduction 97
3.2 Problem Setting 105
3.2.1 Restatement of the Problem 105
3.2.2 Research Questions 106
3.2.3 Assumptions 107
3.2.4 Tasks 108
3.3 Participants 110
3.4 Instrumentation and Measures 113
3.4.1 Analytic Hierarchy Process and ECPro 113
3.4.2 Scales and Calculations 120
3.4.3 Consistency, Reliability and Validity 123
3.5 Procedures 125
3.5.1 Data Collection and Calculations 125
3.5.2 Research Method Flow Chart 128
3.6 Statistical analysis 130
Limitations and Delimitations 134
Concluding Remarks 134

CHAPTER 4

RESULTS **135**

4.1 Introduction 135
4.2 Panel of Experts 137
4.3 Conventional Production Practices 141
4.4 Alternative Production Practices 143
4.5 Criterion Variables 145
4.6 Relative Weights (Intensities) 149
4.7 Ratings 157
4.8 Definition of BAP 162
4.9 Sustainable Performance Indices (SPI) 173
4.10 Hypothesis Testing 174

CHAPTER V

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS **184**

5.1 Introduction 184
5.2 Problem Statement 184
5.3 Researchable Questions 187
5.4 Findings and Conclusions 188
5.4.1 What are the important criteria that must be met in order to perform in a sustainable manner? 188
5.4.2 What are the conventional banana production practices (CPP) in Costa Rica? 189

5.4.3
5.4.4
5.4.5
5.4.6
4.5.7
5.4.8
5.5 Reco
5.6 Conc
Appendix
Appendix
Bibliograp

5.4.3 Are the CPP performing in an environmentally, socially and economically acceptable manner? 190
5.4.4 Are there best available practices (BAP) that have a better environmental, social and/or economical sustainable performance? 191
5.4.5. Should banana production for the export market be abandoned? 192
5.4.6. What areas should be further researched and developed to improve sustainable performance? 193
4.5.7 Is it necessary to significantly change the market component of the system in order to improve the sustainable performance of banana production for the export market? 195
5.4.8 Was the analytical method proposed appropriate to answer the previous questions? 196
5.5 Recommendations 199
5.6 Concluding Remarks 201

Appendix A 206

Appendix B 233

Bibliography 273

LIST OF TABLES

Table 1 - Inputs vs. residuals for the plantation in a banana production system72

Table 2 - Inputs vs. residuals for the packing plant in a banana production system 73

Table 3 - Indices and information needed to calculate waste generation in banana production 74

Table 4 - Waste Generated in Banana Production 75

Table 5 - Panel of Experts 102

Table 6 - Aggregated Two-way Classification 105

Table 7 - Scale of Relative Importance (Saaty, 1996. P. 54) 121

Table 8 - Environmental Sustainable Performance Indicator Scale 122

Table 9 - Social Sustainable Performance Indicator Scale 122

Table 10 - Economic Sustainable Performance Indicator Scale 123

Table 11 - Two-way Classification Experimental Design 132

Table 12 - Procedure for ANOVA 132

Table 13 - Procedure for Testing a Planned Orthogonal Comparison 133

Table 14 - Panel of Experts 139

Table 15 - Rejected Alternative Production Practices Based on Low ENPI 164

Table 16 - Rejected Alternative Production Practices Based on Low SOPI 164

Table 17 - Rejected Alternative Production Practices Based on Low ECPI 165

Table 18 - Rejected Alternative Production Practices Based on Low ISPI......165

Table 19 - Rejected Activities that Merit Review. 166

Table 20 - APP Rejected Because of Unavailability. 167

Table 21 - CPP with Unacceptable Levels of Performance 169

Table 22 - Best
Table 23 - Best
Table 24 - CPP
Table 25 - Expe
Table 26 - Desc
Table 27 - Res
Table 28 - Res
Table 29 - Res
Table 30 - Res
Table 31 - Tab
Table 32 - Desc
Table 33 - Res
Table 34 - Agre
Table 35 - Inde
Table 36 - Env
Table 37 - Soc
Table 38 - Mea

Table 22 - Best Available Production Practices.................................... 170
Table 23 - Best Available Labor Management Practices 172
Table 24 - CPP with Unacceptable Level of Performance........................ 173
Table 25 - Experimental Design Matrix.. 176
Table 26 - Descriptive Statistics of the Two Samples............................. 177
Table 27 - Results from the ANOVA Using MINITAB............................. 177
Table 28 - Results of Comparison of SPIcpp with SPI bap...................... 180
Table 29 - Results of Comparison of SPIcpp to 0.600 Using MICROSTAT.. 180
Table 30 - Results of Comparison of SPIbap to 0.600 Using MICROSTAT.. 180
Table 31 - Tabulation of SPI by Segment of PE.................................... 181
Table 32 - Descriptive Statistics of the Two Segments........................... 182
Table 33 - Results of Comparison of SPIbap to 0.600 Using MICROSTAT.. 182
Table 34 - Agreement to Participate.. 233
Table 35 - Independent Variables... 235
Table 36 - Environmental Effect Intensities (weights) Assigned by PE........ 260
Table 37 - Social Effects Intensities (weights) Assigned by PE................ 263
Table 38 - Mean Value Substituted in Equation to Calculate SPI.............. 266

LIST OF FIGURES

Figure 1 - Resource Versus Consumption.. 22

Figure 2 - Odum's Parachute Theory.. 32

Figure 3 - Axinn's Theory.. 24

Figure 4 - Map of Costa Rica: Banana Growing Region & EARTH College.. 62

Figure 5 - Pairwise Comparison Matrix.. 117

Figure 6 - Methods Flow Cart.. 129

Figure 7 - Foundation Structure for the Environmental Component........... 152

Figure 8 - Foundation Structure for the Social Component...................... 153

Figure 9 - Foundation Structure for the Economic Component.................. 154

Figure 10 - Superstructure for Production Systems................................ 155

Figure 11 - Individual 95% Confidence Intervals for Mean Values............ 178

Figure 12 - Individual 95% Confidence Intervals for Mean Values............ 182

Figure 13 - Macro Level Banana Production Model................................ 206

Figure 14 - Micro Level Banana Production Model................................ 207

Figure 15 - Mega Elements of a Sustainability Performance Index........... 208

Figure 16 - Micro Criteria for an Environmental Performance Index........... 209

Figure 17 - Micro Criteria for an Environmental Performance Index........... 210

Figure 18 - Micro Criteria for an ENPI (Conservation of Biodiversity)......... 211

Figure 19 - Micro Criteria for an ENPI (Pollution Prevention).................... 212

Figure 20 - Micro Criteria for an ENPI (Rational Consumption of Inputs)..... 213

Figure 21 - Micro Sub-criteria for ENPI (Integrated Residual Management) 214

Figure 22 - Micro Sub-criteria for ENPI (Residual Generation).................. 215

Figure 23 - Macr
Figure 24 - Micr
Figure 25 - Micr
Figure 26 - Micr
Figure 27 - Micr
Figure 28 - Micr
Figure 29 - Micr
Figure 30 - Micr
Figure 31 - Micr
Figure 32 - Micr
Figure 33 - Micr
Figure 34 - Micr
Figure 35 - Micr
Figure 36 - Micr
Figure 37 - En
Figure 38 - Soc
Figure 39 - Eco

Figure 23 - Macro Criteria for a Social Performance Index...................... 216

Figure 24 - Micro Criteria for a SOPI (Health Hazard Prevention)............. 217

Figure 25 - Micro Sub-criteria for a SOPI (Prevention Measures)............ 218

Figure 26 - Micro Sub-criteria for a SOPI (Prevention Measures)............. 219

Figure 27 - Micro Sub-criteria for a SOPI (Services)............................. 220

Figure 28 - Micro Sub-criteria for a SOPI (Education)............................ 221

Figure 29 - Micro Criteria for a SOPI (Job Security).............................. 222

Figure 30 - Micro Criteria for a SOPI (Capacity Enhancement)................ 223

Figure 31 - Micro Criteria for a SOPI (Benefits to Local Communities)........ 224

Figure 32 - Micro Sub-criteria for a SOPI (Stress on Community's Health).. 225

Figure 33 - Micro Criteria for a SOPI (Benefits to National Community)...... 226

Figure 34 - Micro Criteria for an Economic Performance Index................ 227

Figure 35 - Micro Sub-criteria for ECPI (Fringe Benefits)........................ 228

Figure 36 - Micro Criteria for an ECPI (Cost of Resources - Inputs)........... 229

Figure 37 - Environmental Component of Banana Production Systems...... 230

Figure 38 - Social Component of Banana Production Systems................ 231

Figure 39 - Economic Component of Banana Production Systems........... 232

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A Systems Method for Evaluating the Sustainability of Ag-production: An Evaluation of Banana Production in Costa Rica

Carlos E. Hernández

Chapter 1

INTRODUCTION

"... we need not merely a vision, but a shared vision, one that guides and unites us in our day-to-day decision making. Such a vision, a common blueprint, can infuse society with a sense of purpose as we try to build a new world, one much more attractive than today's (Lester Brown, 1993, p. 19)."

1.1 Topic of the Dissertation

This dissertation presents a systematic method for evaluating the sustainability of agricultural production systems. It advances a normative philosophy (blueprint) to define sustainable production. It assumes that a systems approach is a suitable and acceptable method that can guide the analysis and support the hypothesis. It establishes a Sustainable Performance Indicator (SPI) to assess the conventional and the best available practices for crop production. The problem is framed using a holistic approach that integrates multiple issues and disciplines within a resource-development framework.

The author explores and assesses the conventional agricultural technology used in the present to produce bananas in Costa Rica. Since there are many ki

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are many kinds and qualities of bananas and many target markets, it is essential to specify the fruit type that is considered in this research. The label "world-class bananas" implies that the fruit meets the quality, service and price standards required by the United States and European markets. It also means that the fruit competes in the open market without the enjoyment of any trade privileges from the receiving country. If the fruit qualifies as world-class, it has a general market acceptance throughout the global free and open market. To achieve world-class status in a very competitive market, the producer must use leading-edge production technology that delivers a standard that is difficult for other competitors to match at a profit making cost (Johannson, 1996).

The object of this exploration is to study state-of-the-art world-class banana plantations in Costa Rica. The leading-edge technologies that have been adopted by progressive producers will be evaluated to determine their contribution towards sustainable development. The results will serve to identify and suggest a path for further improvement.

1.2 Philosophical and Theoretical Framework

This section outlines the author's journey in search of a vision, a blueprint that defines the philosophical and theoretical framework upon which sustainable development can be built and connected to the practice of food production. This emerging paradigm begins by exploring today's scenario, then identifies current models of development, and finishes with a working definition of sustainable agricultural production.

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The twentieth century industrial growth and development paradigm emphasizes economic gains over ecosystem integrity. It is based on reductionist economic models which inadequately recognize ecosystem integrity, ethics and values (Daly and Cobb, 1989). Human wants and needs have prevailed, and natural resources have been regarded as inexhaustible. Furthermore, the allocation of benefits has not always been equitable and just.

Never before has there been more concern for the effects of human activities on the earth's land, water, atmospheric, and biotic resources. Flavin and Young (1993, p. 180) eloquently capture the essence of this interest by stating that --

> *"On its own terms, the modern industrial system is extraordinarily successful... But much of the affluence has been borrowed from future generations. Destruction and degradation of natural assets -- air, land, water, forests, plants and animals species -- have subsidized the profits of many businesses in the late twentieth century. For industries around the world, the debts are coming due."*

In a complementary statement, Brown (1993, pp. 18-20) states that --

> *"The existing economic system is slowly beginning to self-destruct as it undermines its environmental support systems. The question is whether we will initiate the changes in time and manage the process or whether the forces of deterioration and decline will prevail, acquiring a momentum of their own... The question is not only what do we need to do, but how can we do it quickly -- before time runs out and the entire world is caught in the downward spiral...(Brown, 1993, p 20)."*

The Brundtland Commission served notice to the world community that the trend of economic growth threatened the future of humanity. It clearly recognized the cause of the problem and stated that:

"The Earth is one but the world is not. We all depend on one biosphere for sustaining our lives. Yet each community, each country, strives for survival and prosperity with little regard for its impact on others. Some consume the Earth's resources at a rate that would leave little for future generations. Others, many more in number, consume far too little and live with the prospects of hunger, squalor, disease, and early death. (Quoted by Wackernagel, Onisto and Mata. 1995 p. 26)"

The Earth Summit in Rio (1992) serves as testimony that the world community has concurred. Agenda 21 promotes a strategy for change and the Earth Council supports and aids in the needed transition toward a new paradigm of development. However, little has been achieved beyond rhetoric.

"The Earth's population grows daily, poverty spreads, non-renewable resources are further depleted, more waste is dumped in oceans and the atmosphere, the ozone hole continues to grow and CO_2 levels continue to climb. Humanity's impact, or ecological footprint, grows while the global ecosystem's productivity, on which we depend for survival, continues to decline (Wackernagel, Onisto and Mata., 1995. p. 1)."

Going beyond discourse implies making hard choices that are not politically palatable among the empowered minority who feel their status quo threatened. How can it be popular to them if

"the richest fifth of humanity earns over 60 times more than the poorest fifth (Wackernagel, Onisto and Mata., 1995. p. 2)"

and where

"3/4 of current consumption goes to 1.1 billion people who live in affluence, while 1/4 of the consumption remains for the other 4.7 billion people (Wackernagel, Onisto and Mata., 1995. p. 2)"?

Is it not obvious who has to make the sacrifice?

The when, what and how of necessary change is not generally shared. On one side, the paradigm espoused by "Deep Ecology" appeals for urgent constraint of

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constraint of economic growth and a negative human population growth rate; restraint in human activity in favor of ecosystem preservation; and recognition of innate values and equity among species (Colby, 1990). Many insist that the biosphere is already beyond its limits, and predict eminent crisis (Meadows, Meadowsand Randers, 1992). On the other extreme, the disciples of "Frontier Economics" (neo-economists) place their faith in technological solutions, productivity, individuality and self-interest, and values based on market prices. They insist on the necessity of infinite economic growth. They question the urgency of change based on the failure of previous predictions of doom.

In between these extremes, many natural and social scientists are searching for a way of working together to advance sustainability, environmental protection, eco-management, and eco-development. This group seeks to promote the concept that agriculture is a complex system that cannot be abstracted as an industry divorced from nature; to confront the reality that natural resources are limited; to favor long-term over short-term planning; to recognize values that go beyond market price as elements to be considered in an economic analysis; to endorse the search for advanced appropriate technologies; and to encourage grassroots movements to empower people and generate the controlled effervescence of gradual change (Colby, 1990; Solórzano, del Camino, Woodward, Tosi, Watson, Vásquez, Villalobos, Jiménez, Repeto and Cruz, 1991; Beus and Dunlop, 1990; Altieri, 1987). The followers of this paradigm recognize the importance of meeting human needs and integrating natural and social process to redefine values. They concede that if humans do not perce[illegible]

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not perceive and assign proper significance to natural resources, eventually these resources will be depleted, degraded, destroyed, or exchanged for alternative resources of superior monetary value.

Nowhere is the need for change better manifested than in the industrial agriculture of today. The success of the "Green Revolution" is attributed to the industrialization of agriculture. Under this system, high agriculture yields depend largely on inputs of fossil fuel energy rather than efficient conversion of solar energy through photosynthesis. If synthetic inputs are removed, yields fall because soils are exhausted (Hall, 1990). Industrial agricultural models can be maintained as long as the price of fossil fuel remains low. The present market price is not a true reflection of the scarcity of fossil fuels. There is a strong possibility that in less than 30 years, petroleum reserves will be concentrated in only four nations, which can then dictate price to the rest of the world. If this happens, societies that rely exclusively on industrialization models will face catastrophe (Hall, 1990).

Harwood (Committee on Sustainable Agriculture and the Environment in the Humid Tropics - CSA, 1993. p. vii), suggests that a new attitude of stewardship and sustainable management is required if our global resources are to be conserved and at the same time remain productive. He states that,

> *"thoughtful and prompt actions, especially positive policy changes, are required... to reverse environmental degradation caused by improper or mismanaged crop and animal production systems..."*

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However, it is one thing to prescribe change while it is an entirely different thing to implement change.

> *"Decisions concerning the management of natural resources will always be made in the political arena... In the past, many such decisions have been made without adequate information about the consequences of the actions as they relate to near-term and long-term availability and quality of natural resources and vital ecological processes. Frequently these decisions have resulted in the loss of resources or in the need for expensive recovery actions. Thus, the challenge is to provide the best possible information so that decisions can be based on the most accurate predictions of any action (Risser, Lubchenco, Christensen, Dillon, Jacob,Johnson, Matson, Moran and Rosswall, 1993, p. 5)."*

It is especially important to recognize that political issues are affected by specific interest groups and are not always representative of the greatest public good.

The Earth Monitoring and Reporting Program of the Earth Council states that:

> *"Sufficient information is available to make the necessary decisions for a sustainable future; but it is also clear that these decisions are not being made. This lack of government action underscores the need for encouraging people's involvement. In fact, hope for the future depends on people taking up sustainability as their own personal cause. The challenge is to change the way people live in this world by changing the way they see the world, and changing the way people see it by changing the way we live in it (Wackernagel, Onisto and Mata., 1995. p. 2)."*

This necessarily involves empowering people

> *"in building a more secure, equitable and sustainable future, in a spirit of solidarity and common responsibility (Wackernagel, Onisto and Mata., 1995. p. 2)."*

Therefore, a substantial challenge is to seek, collect and provide sound information to the policy makers and their constituencies organized in a way that can be easily understood and translated into appropriate values.

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1.3 Objective

This dissertation accepts the challenge of conceptualizing a systematic method of seeking, collecting and providing sound information in order to evaluate the sustainable performance of Ag-production. It tests this method rating the performance of world class banana production in Costa Rica.

Most research has concentrated on the task of going beyond the Brundtland Commission's (1987) definition of sustainable development

> *("meet the needs of the present without compromising the ability of future generations to meet their own needs")*

and have continuously worked to produce and refine sustainability indicators that measure the present condition and the effects of change (Wackernagel, Onisto and Mata, 1995). This dissertation goes beyond numerical indicators, and begins by proposing a conceptual model in an effort to connect natural and social processes, and search for solutions that take into account the interactions of social, economic and biophysical components. It seeks understanding of the effects of human attempts to control nature by managing agricultural ecosystems.

The immediate task of this chapter is to develop a normative philosophy that can guide sustainable banana production. It acknowledges that sustainable agricultural production can contribute to the sustainability of humanity, but that it is only one element of a complex solution. Furthermore, it should not lead to the false expectation that change will be universally embraced and fully implemented in the near

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1.4 Definitions

1.4.1 Systems Approach

H. T. Odum (In Mitsch and Jorgensen, 1989, p. 101) advises that

> *"as the resources of the world become increasingly limiting to the expansion of the human economy, the management of the planet must turn more and more to a cooperative role with the planetary life support systems, sometimes called stewardship of nature."*

The problems of development are becoming more complex and less solvable by conventional technological means. In the past, society has relied on technical solutions that solve one type of problem only to find that they have created another type (Mitsch, 1993). The narrowness of conventional approaches to analysis and problem solving is the culprit in such mistakes. Solutions to human problems are better solved by finding symbiotic relationships of human and natural mutually reinforcing systems (Odum, H. T. In Mitsch and Jorgensen, 1989). Analysis and problem solving approaches must evolve to meet the challenge of new complexities.

> *"Science is a process, a method of studying reality in order to gain knowledge (Peet, 1992, p 19) ".*

The scientific method is the conventionaly accepted procedure of observation and careful experimentation to obtain facts. Normally it uses a reductionist approach that consists of breaking down the elements of a problem, isolating each element from the rest, and studying each separately.

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"Taken to excess, reductionism encourages concentration on detail to the exclusion of the whole and can be seriously misleading (Peet, 1992, p. 21)."

Reductionism incorrectly assumes that the sum of the parts equals the whole.

A systems approach is a tool that facilitates holistic analysis of a complex system by characterizing its nature in such a way that the decision making can take place in a logical and coherent fashion. It is a

"way of thinking about the set of interconnected parts that makes up the whole in such a way as to bring out the properties of the whole rather than those of the parts (Peet, 1992, p. 25)"

thus, minimizing the occurrence of the

"fallacies of narrow-minded thinking (Churchman, 1968, p. x)."

Systems are classified as isolated, open, or closed depending on how they interact with their surroundings.

"An isolated system exchanges neither energy nor matter with its environment (Peet, 1992, p 14)."

Isolated systems have not been identified on earth, not even in the laboratory. A closed system exchanges only energy with its surrounding environment.

"The earth is a closed system, since only solar energy comes in and only heat is rejected to outer space (Peet, 1992, p 14)." In contrast, "an open system exchanges both energy and matter with its environment. Thus, all living organisms, ecosystems, and economies are open systems since they consume food, reject wastes, and take heat from or give it to their environment (Peet, 1992, p 14)."

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Therefore, sinks ("the utimate destination of material or energy flows (Meadows, Meadows and Randers, 1992, p 278)"), transformation processes and throughputs ("the flow of energy and materials needed to keep the economy functioning (Meadows, Meadows and Randers, 1992, p. 279)"), are critical elements in defining and understanding systems.

The first step in studying a system is to define the problem. Then it is necessary to determine the appropriate spatial and temporal limits of the system. The dimensions of the system are fundamental in measuring the potential of the study and are set according to its objectives. If the system's boundaries are set too large, the perceived and measurable signals may be too aggregated. On the contrary, if the boundaries are set too small, the information may be too complex, troublesome to synthesize, and thus, very difficult to interpret.

To analyze agricultural production systems, del Camino and Muller (1993) recognize eight levels of spatial limits or scales of analysis: global, regional, national, regions within a nation, local, farm, agronomic procedure, and microscopic systems. They identify the farm level as the convenient level for studies of sustainable agricultural production. This level facilitates the analysis in detail and the identification of internal and external causes and effects, and appropriate opportunities for actions. As recommended by del Camino and Muller (1993), care is taken not to isolate the analysis and ignore interaction with vertically (systems defined by larger and smaller scales) and horizontally (different sub-systems at the same scale) overlapping chains of connections among components and systems. Therefore, it is necessary to consider, in lesser deta

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lesser detail, agricultural production in at least three additional levels or scales of organization -- global system, nation, and agronomic procedure. Furthermore, to understand the implications of agronomic procedures, it is sometimes necessary to understand the microscopic scale.

The next step is to break down the system into functions or components. In essence, components are points of transformation or sinks of energy and matter. They are interrelated by cause and effect, stimulus and response. In substance, interrelations between components are evidenced by throughputs. Monetary units are the conventional way that economists account for throughputs in an economic system (Hall, Cleveland and Kaufman, 1992).

As stated before, agricultural production systems are open and pervious to interactions from other systems. Inputs and outputs of a system under study are recognized by the throughputs that necessarily cross the arbitrary boundaries set between two horizontal or vertical sub-systems (Meadows, Meadows and Randers, 1992). In this manner, production systems are intimately related to other systems and are subject to effects from changes made in adjacent systems (Peet, 1992).

From the human ecology perspective, Axinn (1988, pp. 10-12) summarizes this process with the following statement:

> *"Wherever there are human beings, they carry out certain basic functions... From a systems perspective these functions may be viewed as components, linked with each other so that change in any component affects the entire system. Any interaction with outside systems will be reflected by change within the system...*

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There are various forces pushing in the direction of change, and counterforces pushing in the direction of continuity. At any particular point in time, things are as they are because the forces in one direction balance the forces in other... no outside intervention occurs in a vacuum. Change results from introduction of additional forces in the change side, or from reduction of some forces on the continuity side."

In contrast to the holistic character of the systems approach, a reductionist approach consists of breaking down the elements of a problem, isolating each element from the rest, and studying each separately. In the end, the different elements are assembled together assuming that the sum of the parts equals the whole, and no adequate consideration is given to the synergism among elements. Consequently, reductionism is not an appropriate approach for studying open systems.

Using scientific knowledge and experience, the reaction of every action can be traced through the system and behavior predicted. Based on this prediction, indicators can be developed to measure the level of performance of each component, adjustments can be made to improve performance, or components and standards may be modified to fit reality. This process is called modeling, and often is accompanied by an effort to assign mathematical formulas to quantify stimulus and response. However, it is important to keep in mind that a model is only a simplified representation of reality.

"It is our best attempt to symbolize our thoughts, but it is only a model of those thoughts (Meadows, 1992, p. 105)."

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Appropriately, Daly and Cobb in their book -- For the Common Good (1989)-- warn the reader of the dangers of placing too much credence on models.

Finally, systems thinking is guided by the following principles:

1. A system must be analyzed through different viewing windows or frames. Churchman states that –

   "The systems approach begins when first you see the world through the eyes of another (1968, p. 231)."

2. Each window or frame has strengths and weaknesses, and no one frame fully explains reality. Churchman's point of view is that –

   "The systems approach goes on to discovering that every world view is terribly restricted (1968, p.231)."

3. There are no correct or incorrect views, just different ways of interpreting information. Churchman's reaction is that –

   "There are no experts in the systems approach (1968, p 231)."

4. Analytical thinking is opportunistic. Churchman states that –

   "When you postpone thinking about something too long, then it may not be possible to think about it adequately at all (1968, p. 8)."

5. The challenge of systems thinking is to learn what everybody knows by re-addressing what seems obvious. From this point of view, "The systems approach is not a bad idea (Churchman, 1968, p. 232)."

The product of this research is a systematic analysis and the development of a banana production model that assists stakeholders with identifying the components and their interactions, and the inputs and the output at predetermined scales. This facilitates the analysis of alternative technologies and their effects on the system in a holistic manner and the evaluation of them as to their effective contribution to sustainable development of agroindustry.

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This dissertation is the author's attempt to assist the reader in seeing the world of banana production through a case example and the author's personal experience in the banana industry. As such, it is restricted and skewed. It is the author's interpretation of the information available which leads to the conclusion that little time remains before remediation of damages caused by unsustainable production practices is no longer an option. Thus, this is the opportune moment to go back to the basics and verify what seems obvious using a multidisciplinary framework. It is necessary to see banana production through the eyes of entomologists, soil and crop scientists, toxicologists, social scientists, economists, ecologists, producers, banana workers, communities, wholesalers, retailers, produce suppliers, consumers, and governments. Each view exposes significant aspects, yet all are restricted and do not provide the entire illustration. Each observer has a unique porthole that provides a section of the entire panorama. At the same time, each spectator interprets the pictures in a different manner, and forms a singular conception. Consequently, there are no right and wrong impressions, and accordingly, there are no experts. Every one's notion is meaningful, and the summation of views approximates the intact reality. Therefore, the larger the number of vistas the greater the precision, and the more meaningful the vision.

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1.4.2 Sustainability and Sustainable Development

1.4.2.1 Introduction

Sustainability and sustainable development are terms often used but seldom understood. Both are essential elements of the philosophical and theoretical framework for this dissertation. Therefore, it is necessary to move beyond stock definitions and analyze thoroughly the significance and implications of their meanings. This section begins by proposing an overall simplified definition, then expands to its significant components. Next, it integrates innovative pertinent theories on how to achieve sustainable development, and exposes three fundamental conditions for it to occur. Finally, it explores the key elements of a definition for sustainable agricultural production.

1.4.2.2 Sustainability

According to Wackernagel, Onisto and Mata (1995),

> *"In essence, sustainability is a simple concept: living equitably within our ecological means."*

The wording may be simple but a deep probe requires a complex explanation. Because of complexity, it is essential to use a systems approach.

As stated in the previous section, sinks and throughputs are important elements in defining and understanding systems. Furthermore, they constitute the foundation for the definition of sustainability. The Laws of Thermodynamics govern sinks and throughputs.

> *"The First Law of Thermodynamics, the law of conservation of energy, states: Energy can be neither created nor destroyed, only converted from one form to another. When one energy form is converted into others, the total resulting energy remains the same... The accounts always balance; no exception has ever been identified (Peet, 1992, p. 33)."*

Therefore, the solar energy that penetrates our atmosphere must equal the total energy captured, transformed and stored plus the energy dissipated as heat into space. However, the capacity to do work with the transformed energy is not the same as that of the original energy. This leads us to the Second Law of Thermodynamics.

> *"The Second Law of Thermodynamics - the entropy law - can be stated as follows: All Physical processes proceed in such a way that the availability of the energy...decreases (Peet, 1992, p. 36)."*

This means that no transformation of energy is 100% efficient. In each progressive transformation energy is degraded. The result is that each transformation yields a new form of energy which is less available to do work. The Second Law of Thermodynamics highlights the existence of finite limits for earth and ecosystems.

Notwithstanding that natural processes conform to the laws of thermodynamics, viewed from a global spatial and temporal scales, ecosystems are self-organizing and self-sustaining and contribute to reduction of global entropy. According to Easterbrook (1995, p. 661)

> *"the complexity hypothesis posits that a function of life is to defy the second law of thermodynamics... Complexity theorists believe... that in some manner not yet grasped, the universe came prewired to favor complex systems over entropy."*

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This is accomplished through elaborate interactions of matter and energy which are driven by an external source of energy -- the sun (Peet, 1992).

> *"The conversion by plants of solar energy from outside the biosphere to biomass (matter) within it is the only means by which living systems, including humans, can circumvent the Second Law of Thermodynamics and decrease biospheric entropy (van den Berg and van der Straaten, 1994, p.50)."*

Captured solar energy is transformed and stored as stock or flow resources. The transformation of solar energy into stock resources requires millions of years. Stock resources are referred to as nonrenewable resources because they can not be replenished within temporal limits that are relevant to human existence. In contrast, solar energy can be transformed and stored as flow resources in a relatively short period of time. Flow resources are referred to as renewable resources (Peet, 1992).

Through the process of photosynthesis, solar energy plus minerals existing in the ecosystem are transformed into organic matter. As a byproduct, high quality energy is transformed into waste products, and dissipated heat. Other living organisms consume the energy stored in organic matter to transform them into other types of organic matter and into waste, releasing heat in the process. Through a complex cycle, decomposing organisms further transform organic waste matter until it is mineralized with waste generation and heat loss at each step of transformation. In this transformation process, energy is temporarily stored in the form of renewable resources but eventually degrades and dissipates.

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Regardless of the increase in entropy of each transformation, sustainability is theoretically possible because open and closed systems receive energy (and, for open systems, matter) from their surroundings. These systems can theoretically go on forever provided solar energy keeps coming in (Peet 1992, p. 42). Wackernagel, Onisto and Mata (1995) conclude that a system is sustainable as long as the average rate of energy and matter consumed, in all forms, equals their average replenishable rate.

Economics is the methodology used by humanity to manage the distribution of land and resources. Technological breakthroughs have falsely encouraged people to believe that there are no limits to this world (Peet, 1992). Humanity has found ways to efficiently extract resources from nature. Progressively, stored energy has been consumed without consideration of future generations, and many flow resources are being consumed far beyond their replenishable level (Meadows, Meadows and Randers, 1992). Furthermore, humanity, through technology, discovered how to create synthetic materials, some which are difficult to transform by natural processes into other forms and some which are toxic, and has thus been able to bypass natural processes. These anthropogenic activities have temporarily empowered humanity to survive in hostile environments in population sizes beyond the system's sustainable carrying capacity. The results are an increase in the rate of waste generation beyond the assimilation rate (Meadows, Meadows and Randers 1992).

The prevailing neoclassic economic approach promotes accelerated transformation of resources (production) and consumption. This economic paradigm

> *"necessarily and unavoidably degrades the resources that sustain it (Peet, 1992, p.37)". "In strong contrast to economic systems, ecosystems accumulate energy, matter, and order (Peet, 1992, p. 45)."*

Thus, people should take a careful look at ecosystems, make an effort to understand them, and manage them accordingly. Unless humanity reduces consumption, improves process efficiency and recycling, and/or develops technology to capture more solar energy before it is dissipated into space, the ecosystem will increase entropy and the economic system will eventually run out of available energy to do work.

In summary, an economic system that consumes resources at excessive rates leads to depletion and scarcity of vital resources to sustain it. An economic system that generates waste beyond the ecosystem's capacity to assimilate it, degrades and eventually is not able to provide the basic resources needed to sustain it. Finally, a system that does not check population growth rates, exacerbates resource consumption and waste generation and leads to unsustainable effects (van den Berg and van der Straaten, 1994).

1.3.2.3 Sustainable Development

Sustainable development implies growth, resulting in increased consumption. Rachel Carson, Paul Ehrlich, Norman Myers, among others, question

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question Earth's ability to support further growth, casting doubt on the possibility of achieving sustainable development (Easterbrook, 1996). The following synopsis of theories will explain how sustainable development can take place.

George Jacobson (quoted by Easterbrook, 1996, p. 659) declares that

> *"There is almost no circumstance in which something isn't changing the natural system. The system may seek an equilibrium but it's never allowed to get there. So we might as well not expect the classical balance of nature to exist."*

H. T. Odum (personal communication, August 1995) elaborates by stating that ecosystems are constantly in flux. They have the ability to redesign themselves in accordance with the following parameters: a) the capacity to capture solar energy and transform it into other forms, b) the capacity to store it temporarily, and c) the consumption rate by living organisms in the system. As the availability of stored resources increases, life is stimulated and the consumption rate increases (See figure N°1). At a particular point in time, consumption is equal to the replenishable rate. As consumption continues to climb, organisms start to draw upon accumulated resources until all are consumed. At this point, the ecosystem adjusts, populations decrease, and consumption falls drastically. This process is repetitive at all levels (spatial and temporal limits) of ecological hierarchy. Thus ecosystems are never truly stable but in constant flux and adjustment. On a global spatial and geologic time scale, there are evidences of several cycles, which involve high amplitude (magnitude of the adjustment) and low frequency (time between adjustments). The smaller the limits of the system, the smaller is the amplitude and the higher is the frequency.

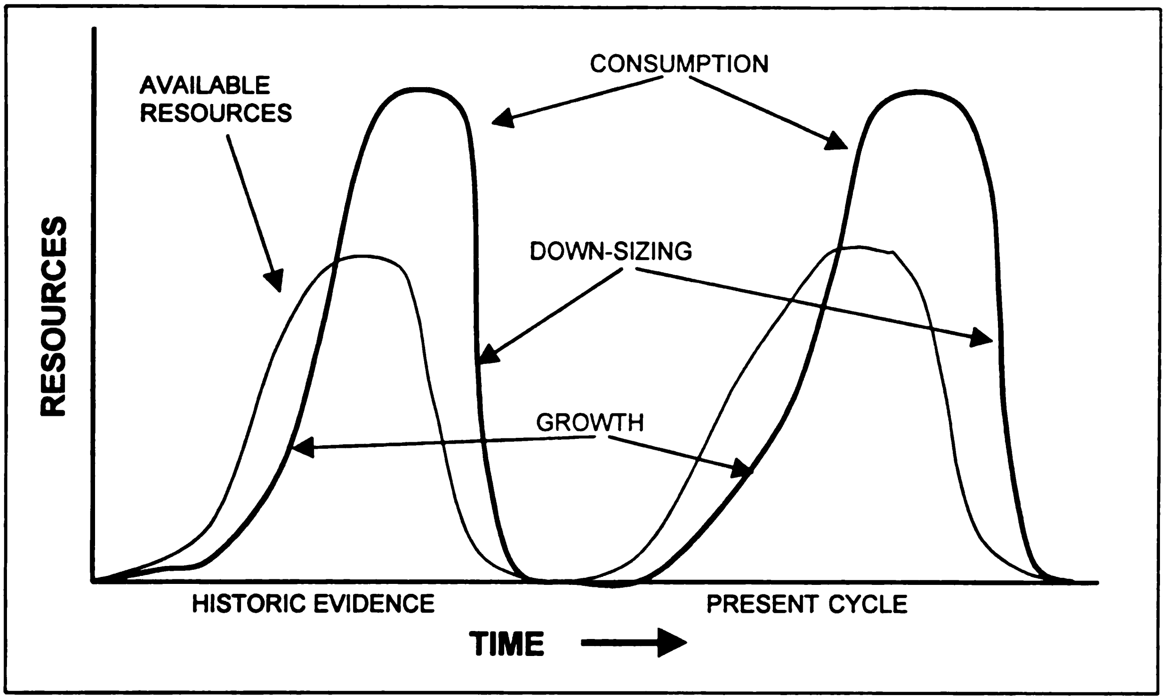

Figure 1 - Resource Versus Consumtion

Odum (personal communication, August 1995) believes that the present economic system has reached its peak, that the ecosystem is beginning to redesign itself, and the probability of drastic effect on humans are high.

Fortunately, humans have the rational capacity to control the fall by down-sizing in an orderly manner. Odum calls it the "*parachute theory*" (personal communication, 1995) By so doing, humans can manage the process to slow it down and to control the magnitude of the adjustment. In theory, society can choose a datum level of consumption that permits us to flux at a higher frequency with a low amplitude (See figure N° 2). This is equivalent to relative stability for an indefinite time (sustainability).

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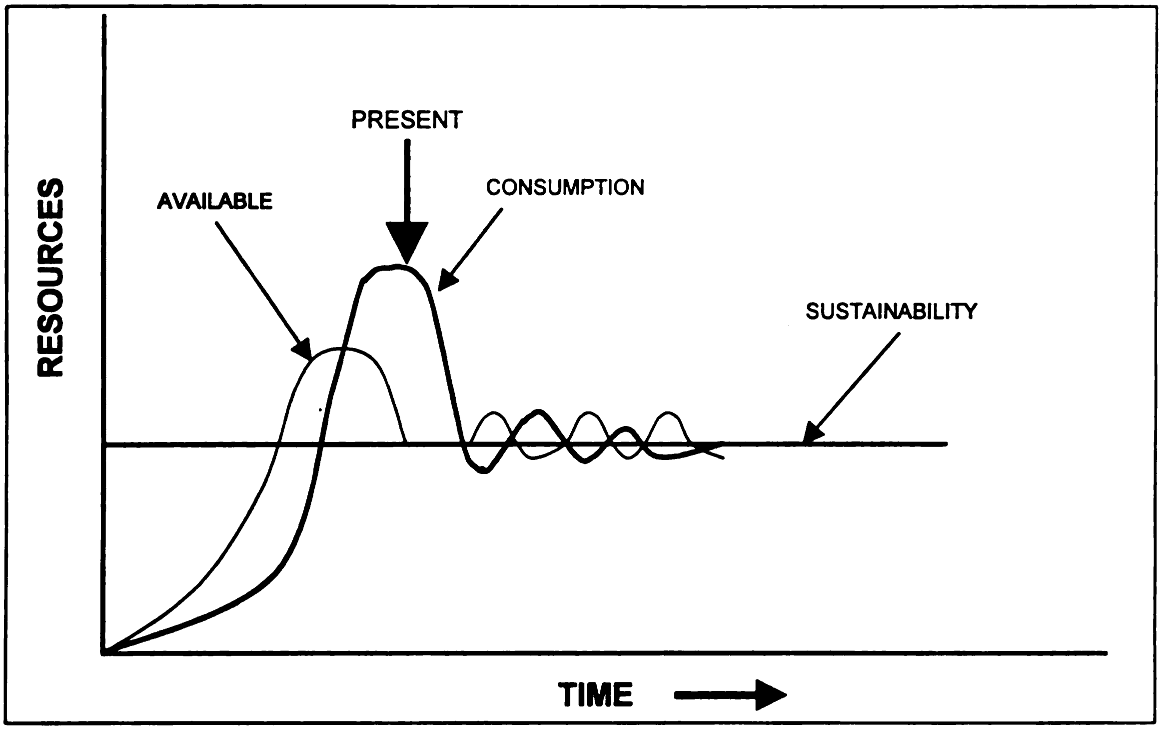

Figure 2 - Odum's Parachute Theory

Viewed from the social perspective, George Axinn (RD 876 class notes, 1993) proposes that the levels of economic development are cyclic and that at any one time components of a system, at any scale, may be underdeveloped, developed or overdeveloped (see figure N° 3). Components that are overdeveloped have excessive demands that cannot be met by the support systems and thus decline to the developed state, and momentum will cause them to decline further until they are underdeveloped. Systems, which are underdeveloped, have the capacity to grow to the developed state because their consumption is below the support system's capacity and, once developed, momentum carries them to over-development. The cycle repeats itself.

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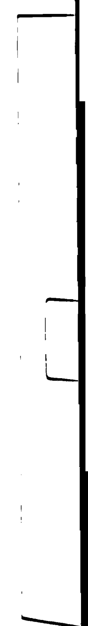

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Theoretically, societies can control the magnitude and frequency of the cycle, with the purpose of achieving a relative stability, by controlling negative and positive growth.

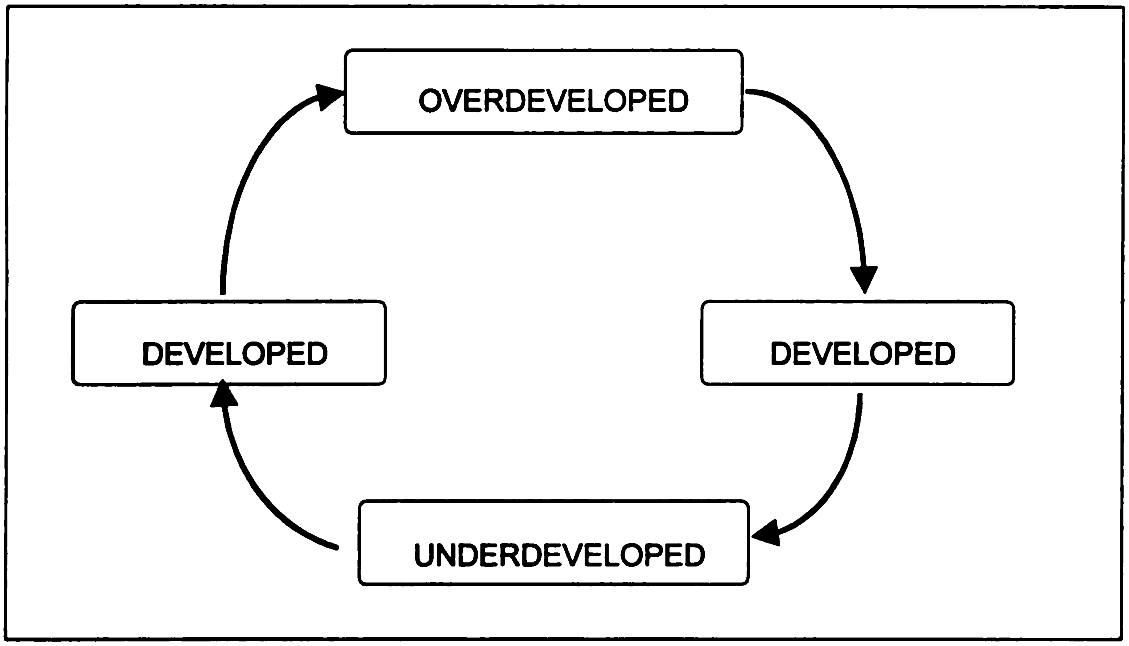

Figure 3 - Axinn's Theory

Both theories hold true as long as population growth is stabilized. Piel (1992) asserts that as human well-being increases, population growth decreases and has a tendency to stabilize. Human well-being is tied to human health

> *"which includes, not only the need for economic goods, but also that for satisfactory social relationships and favorable natural environment (Huss, 1994, p. 14)."*

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According to Langmore (1994, p. 55),

"development is about improving human well-being, increasing choices, and strengthening economic security. It is a mistake to aim simply for improvement in efficiency in the hope that in the long run this will be associated with improvements in equity. Trickle down policies have failed."

Therefore, social equity means that those that have must promote development for those that have not.[1]

Careful examination indicates that Axinn's theory is harmonious and complementary to Odum's theory. The integration of both theories allows us to conclude that ecologically and socially, through sustainable development (simultaneous positive and negative growth), it is possible to achieve sustainability.

The achievement of sustainable development requires understanding of people's complex role in an ecosystem. Society has created an economic system, which governs the exchange of goods and services among people. To facilitate trade, values are artificially measured using money. In today's consumer society, actions are motivated by the certainty that monetary benefits will surpass costs. Change will not occur unless it is economically feasible and attractive to those that have the power to change. As Magi O. Brian (personal

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1 If we apply Rawls's Theory of Justice in combination with Axinn's theory, all members of society should be in agreement with this statement because at some point in time they will be in a position to help and in another they will need help.

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communication, visit to EARTH College 1995), President of the U. S. Fish and Wildlife Foundation, says *"If it pays, it stays"* .

However,

> *"the primary objective of any economic activity is the production and distribution of goods and services for the benefit of humanity (Georgescu-Rouegen, 1976 quoted by Huss, 1994, p. 16)."*

From this point of view, economic development is an essential element of sustainable development.

> *"On the other hand economic development, misunderstood as mere growth, threatens the autonomous ability of the individual, the community and the world as a whole (Huss, 1994, p. 16)"*

to promote human well-being.

In summary, sustainable development implies change from a strategy of maximizing economic growth and production to minimizing present and future human suffering. It means reducing ecological destruction by reducing the rate of demand for renewable and non renewable resources. It means improving the quality of life of the less empowered people by controlling the consumption of the wealthy privileged class. However, unless change is economically feasible it generally will not occur.

Based on the previous discussion and information gathered from the literature, the next section recognizes the fundamental elements of definitions for sustainable agricultural production and posits a specific definition for this dissertation (see p. 28).

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1.4.2.4 Sustainable Agricultural Production

Sustainable Agricultural Production has several definitions. The following are common concepts:

> *"long-term maintenance of natural resources and agricultural productivity; minimal adverse environmental impacts; adequate economic returns to farmers; optimal production with purchased inputs used only to supplement natural processes that are carefully managed; satisfaction of human needs for food, nutrition, and shelter; and provision for the social needs of health, welfare, and social equity of farm families and communities. All definitions embrace environmental, economic and social goals...(CSA, 1993, p. 22)."*

Based on del Camino and Muller (1993. p 29), sustainable agriculture is a set of human interventions that effectively and rationally manage resources and the agroecosystem to satisfy the changing necessities of people, while maintaining or improving the resource base, avoiding environmental degradation, and assuring in the long run a productive and equitable development. In compliance with the previous concepts, sustainable agricultural production systems must fulfill the following objectives:

a. Maintain or improve the natural resource base
b. Avoid environmental degradation
c. Maintain production and productivity
d. Minimize purchased inputs
e. Distribute costs and benefits in an equitable manner
f. Respect the values and principles of the society
g. Satisfy present and future human needs for food, nutrition, health, welfare, and shelter

h. Enhance the quality of life of the farmers and society as a whole.

For the purpose of this dissertation, sustainable production of world-class bananas is defined as follows:

> ***The sustainable production of world-class bananas is a broad spectrum of agro-cultural practices [2] that includes the efficient and rational use of natural resources and the agroecosystem.[3] It seeks to ensure long-range production, productivity, and profitability by maintaining and improving the resource base and preventing environmental degradation. It distributes costs and benefits fairly and equitably, and respects community values and principles, all with the objective of satisfying society's present and future needs, and improving the quality of life of the community.*** *(Synopsis of concepts expressed by del Camino and Muller, 1993; and Tabora, 1991; and CSA, 1992)*[4]

Agroecology and Ecological Engineering are disciplines that encompasses methods which can assist in achieving the goals of sustainable agricultural development, and are the subject of the next sections.

1.4.3 Agroecology

Natural systems are highly diversified and are structurally complex. These properties

> *"provide a natural mature ecosystem with a measure of stability in a fluctuating environment (Altieri, 1983, p. 15 quoting Murdoch,*

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2 The art, customs and science of managing land, crops and the people involved in it.

3 An Agroecosystem is an ecosystem that has been disturbed by humans using soil resources to produce plants and animals for their immediate consumption or for further industrial processing. Therefore, the ecosystem is subjected to ecological as well as socio-economic constraints (Mata and Quevedo, 1990 and Altieri, 1987).

4 Defined by Hernández, C. 1996. Guácimo, Limón: Escuela de Agricultura de la Región Tropical Húmeda. Edited by: Rincón H., Fallas, C. and Alfaro, M., and translated to English by Judy, W.

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1975). Severe stresses in the external physical environment, for example, (such as a change in moisture, temperature or light conditions) are less likely to adversely affect the entire system, for in the presence of a highly diversified biota, numerous alternatives exist for the transfer of energy and nutrients through the system. Hence, the system is capable of adjusting and continuing to function with little if any detectable disruption. Similarly, internal biotic controls (such as predator-prey relationships) prevent destructive oscillations in population numbers further promoting the overall stability of the system (Altieri, 1983, p 15)."

Industrialized conventional agriculture simplifies the ecosystem by introducing human intervened systems (agroecosystems) of few crops and animals (Altieri, 1983). The objective of agroecosystems is to create managed system that can efficiently capture and transform solar energy into resources easily available at levels of productivity capable of satisfying human needs and generating economic profit. In exchange, the agroecosystem loses its integrity and flexibility which in turn affects compatibility, resiliency, longevity, stability, and renewability (Tabora. 1991).

"The net result is an artificial ecosystem which requires constant human intervention for its operation (Altieri, 1983, p, 15)."

Industrialized agroecosystems have proven capable of high yields, but they are very fragile and susceptible to severe stresses caused by the external physical environment (Altieri, 1983). They behave as immature ecosystems with diminished ability to

"perform protective functions in terms of nutrient cycling, soil conservation and population regulations. The functioning of the system is thus dependent upon continued human intervention (Altieri, 1983, p. 17)".

Modern industrialized agroecosystems require considerable amounts of renewable and non-renewable resources from outside the system to substitute function

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functions done by nature in less disturbed systems. Furthermore, waste is generated and introduced into a simplified system that has a reduced assimilation capacity. Environmental degradation and non-sustainable growth evidence the result of irrational resource use and waste generation.

The solution is to design alternative production ecosystems that are similar in structure to natural systems. Altieri (1983, p. x) defines alternative agriculture as

> *"any approach to farming that attempts to provide sustained yields through the use of ecologically sound management technologies. Strategies rely on ecological concepts, such that management results in optimum nutrient and organic matter cycling, closed energy flows, balanced pest populations and enhanced multiple use of the landscape."*

> *"The scientific discipline that approaches the study of agriculture from an ecological perspective is herein termed 'agroecology' or 'agricultural ecology' and is defined as a theoretical framework aimed at understanding agricultural processes in the broadest manner. The agroecological approach regards farm systems as the fundamental units of study, and in these systems, mineral cycles, energy transformations, biological processes and socio-economic relationships are investigated and analyzed as a whole. Thus, agroecological research is concerned not with the maximization of production of a particular commodity, but rather with the optimization of the agroecosystem as a whole. This tends to refocus the emphasis in agricultural research away from disciplinary and commodity concerns and towards complex interactions among and between people, crops, soil, livestock (Altieri, 1983, p. x)", economy, and environment.*

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1.4.4 Ecological Engineering

Ecological engineering is an emerging discipline and there is much disagreement on precise definitions. The task to be accomplished by the Scientific Advisory Committee (SAC) of the Scientific Committee for the Problems of the Environment (SCOPE) on Ecological Engineering, of which the author is a member, is to reconcile differences and arrive at acceptable definitions.[5] The author is not excited over defining a new discipline. The important issue is to recognize that there is a new paradigm developing which includes concepts and techniques that merit adoption.

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5 The following are a few of the definitions presented to the November 1995 SAC-SCOPE meeting in Estonia. The challenge is to extract from them what is useful and develop a operational definition for this dissertation. According to Straskraba (Czech Academy of Sciences), ecological engineering is the use of technological means for ecosystem management based on profound knowledge of the principle on which natural ecological systems are based, and transfer of this knowledge into management in such a way that the cost and impacts are minimized. According to Ann Marie Jansson (Stockholm University), ecological engineering is the design of human society in harmony with the natural environment for the benefit of both. According to Mitsch (Ohio State University), it is the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both. According to Prof. Yan (Chinese Academy of Science), ecological engineering is an overlapping science that makes the necessary connection between ecology, technology, economics and sociology for sustainable development. Mitsch (personal meeting notes) lists the fundamental concepts of ecological engineering as follows:

- "Self-design (self organization) - Man plants the seeds but nature will choose the best one for the system."
- "Ecosystem conservation - Do not throw parts of the systems away because you may need them later (conservation of biodiversity)."
- "Restoration as the acid test -- Fix the damage that we have done. As we do it, we test the theory."
- "Focus on biological systems."

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Ecological engineering, as interpreted by the author, implies limited human intervention on ecosystems through design and management of productive processes that use integrated knowledge of ecology, technology, sociology and economics for the mutual benefit of both society and the environment. At the plantation level, it is the integrated design and management of human intervention and disturbance of the ecosystem, so that the waste of one subsystem or process becomes the resources of a second subsystem.[6] This process generates a resource cycle that approximates the natural nutrient cycle of balanced ecosystems.

Applying the previous definition, eco-managers control disturbance and identify and track all components that generate waste. Ecological Engineers design and formulate clean and appropriate technologies[7] that eliminate, substitute or minimize undesirable inputs and processes. Together managers and designers work to minimize intervention and maximize production by using the capacity of an ecosystem to adapt and self-design. Ecology is the basic science used to understand the interaction between organisms and the environment. System analysis is the management method of tracking sinks and

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6 This definition is a product of discussion at the Estonia SAC-SCOPE conference and not originally mine. It is part of my notes on the conference but no individual credit is included.

7 Cleaner technologies have three basic objectives: (i) to generate less environmental pollution (water, air and soil) per unit of production, (ii) to generate less waste per unit of production, and (iii) to use less natural resources (water, energy raw materials) per unit of production. Note that cleaner technologies do not mean zero pollution. It is a dynamic concept that has to be reviewed and results fed back to the system constantly to

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throughputs. Sustainability indicators, such as energy efficiency and waste, not money, are the common denominator of value.

Ecological economics is a tool necessary to keep score and measure economic success or failure. Through multidisciplinary task forces, the negative effects are minimized, the environment is conserved and biodiversity is protected.

Using Ecological Engineering concepts, the best management practices can be defined and implemented into the production system. However, it is necessary to evaluate the results in order to introduce feedback mechanisms with appropriate signals to correct and improve the system. The following section defines evaluation through matrix analysis and identifies descriptors and indicators for sustainable banana production.

1.4.5 Monitoring Sustainability

1.4.5.1 Introduction

As stated previously, most experts agree on three basic conditions for sustainable development -- environmental stability, economical feasibility, and social acceptance and justice. The problem is how to measure and evaluate

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incorporate in the system of production the best technologies available at a particular point in time.

these conditions without undue abstraction so that there at least is an ordinal ranking of achievement.

Pure economic theory only accounts for values that show up in a perfect market system.

> *"To introduce into this picture judgments about relative values or purposes not correlated with price would disrupt the entire discipline (Daly and Cobb, 1989, p. 93)."*

Exceptions or market failures are identified as externalities and a modest attempt is made to correct them. However, the corrections do not take satisfactory account of the significance of the environment, consider accurately cultural fitness or equity, or the welfare of future generations (van der Bergh and van der Straaten, 1994; Daly 1991). Consequently, policy decisions routinely fail to acknowledge these components (van der Bergh and van der Straaten, 1994, p. 103) because analytical tools used rely heavily on mathematical economic models, such as Cost Benefit Analysis or National Accounting System, which are assumed to be value-neutral. However, society is not value neutral and the models fail to portray reality (Daly and Cobb, 1989, p. 95).

In hopes of solving the problem, Ecological Economists have developed procedures for quantifying qualitative elements such as intrinsic values, principles and ethics. These methods have a danger of assigning precise monetary values and encompass all components through imprecise and indirect procedure. The non-expert end-users, such as politicians, may assign excessive faith to the number value to make policy decisions that have monumental effect on s

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on society. Daly and Cobb (1989) refer to this as the "Fallacy of Misplaced Concreteness".

Naes (1986, p. 510) suggests that the solution is to be found in philosophical concepts and states that

> *--"What is needed is a methodology of persistently connecting basic value judgments and imperative premises with decisions in concrete situations of interference and noninterference in nature. What I therefore suggest is that ...scientists repeatedly and persistently deepen their arguments with reference to basic value judgments and imperative premises. That is, they should announce their normative philosophy of life and discuss environmental problems in their most comprehensive time and space frame of reference."*

In summary, disagreements and discontent with available methods justifies the necessity for further research to find an integrated analytical approach that assigns careful and explicit attention to the complex dynamic processes that integrate

> *"economic activity, the physical-material output, the environmental consequence, and the welfare impact (van der Bergh 1994, p. 4)".*

Care should be taken to avoid falling into the same mistakes and indulge in "Misplaced Concreteness". Consequently, the following tasks claim relevance:

- State a normative philosophy to reach sustainable production.
- Recognize descriptors with proper and measurable indicators of sustainability.
- Advance a method to judge qualitatively the effects of production strategies in relation to the accomplishment of the normative philosophy, and to translate this judgment through a holistic and systematic method into quantitative ordinal indicators.

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1.4.5.2 Sustainability Accounting

Howard Brown (1996. p. 2-3) gives new meaning to Darwin's "survival of the fittest" by slightly modifying it to "survival of the fitter". This implies that those that survive are the *"most willing and able to fit into their environment"*. He further illustrates his point through Howard Odum's

> *"often-quoted assertion that one can understand a system only by understanding the system into which it fits (the environment)".*

If the banana industry wishes to survive, it must create new and innovative mechanisms to understand and measure its fitness for success. Thus, the information needed must go beyond the financial balance sheets and also include environmental and social elements.

Bayley and Soyka (1996, p.14) introduce the concept of environmental accounting and define it as a set of tools used to gather and provide numerical information to track the accomplishment of environmental goals. They warn that a system should respond to internal needs rather than those outside the organization and thus any accounting system should be tailor made. They also suggest that a good practice is to start small and grow as you learn and acquire experience.

Metcalf, Minter and Hobson (1996. pp. 7-11) introduces the environmental performance indicator (EPI) and defines it as

> *"a tangible measure that provides a reference point to track progress in a specific environmental area"*

and lists the following best practices:

- Use of a bundle of objective measurable-indicators.
- Indicators have meaningful units.
- EPI data are collected and reported periodically.
- A structured reporting mechanism is utilized.
- Quantitative goals are established for each indicator.
- Tracks are analyzed and continuous improvement is pursued.

Furthermore, Metcalf, Minter and Hobson (1996. pp. 7-11) notes the following benefits of using EPI:

- Defines quantitative rather than less effective subjective, often ambiguous, goals and tracks progress towards achieving them.
- Highlights areas of excellence and serves as a means of recognizing employees' efforts.
- Demonstrates continuous improvement and a quest for excellence.
- Identifies weak spots in environmental mangement which need further attention.
- Allows management to allocate limited resources in an efficient manner.
- Provides a communication tool to convert accurate and concrete environmental performance information to stakeholders.
- Provides a mechanism for establishing accountability for environmental results and reward systems that attach employee compensation to performance goals.

EPI are not enough because they do not take into consideration economic and social indicators. However, EPI provides the ground work for the elaboration of the Sustainability Performance Indicator (SPI) in this dissertation. All the general elements previously discussed related to EPI are valid for SPI.

Environment and economics come together when eco-efficiency is considered. The Business Council of Sustainable Development (Fiksel, 1996) defines an eco-efficient firm as a

"corporation that achieves more efficiency while preventing pollution through good housekeeping, materials substitution, cleaner technologies, and cleaner products and that strives for more efficient use and recovery of resources."

Cleaner processes modify technology to reduce pollution and waste; cleaner products imply a redesign of products so that they generate less pollution and waste throughout their life cycle; and efficiency involves rational use of resources so that fewer materials and less energy is used per unit of value produced. In this new age an economically successful firm must design safe and eco-efficient products and processes.

Fiksel (1996) emphasizes the necessity to include high-level environmental metrics to give appropriate signals to decision makers. He gives the following examples of performance metrics or indicators:

- Energy consumed during product life cycle.
- Total fresh water consumed during processing.
- Toxic and hazardous materials used in production.
- Total waste generated during production.
- Hazardous waste generated during production.
- Air emissions and water effluents generated during production.
- Greenhouse gases and ozone-depleting substances released during life cycles.
- Percent of recyclable materials available at end of life.
- Percent of product recovered or reused.
- Purity of recyclable materials recovered.
- Percent of product disposed or incinerated.
- Fraction of packaging or containers recycled.
- Average life-cycle cost incurred by manufacturer.
- Purchase and operating cost incurred by the customer.

Once more, energy and waste (throughputs) show up as key indicators.

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1.4.5.3 Evaluation Matrix

Matrix analysis is a common and useful tool in environmental impact studies. Its virtue is that it is a viable and proven way of synthesizing, organizing, visualizing, and valuing, in a systematic manner, the multiple elements which contribute to the environmental impact of an action (Edmunds and Letey, 1975). The best known matrix method for environmental impact analysis was developed by Dr. Luna Leopold in 1971 (cited by Nava from López, 1991). It consists of 100 independent variables laid out on the horizontal axis and 88 dependent variables listed on the vertical axis. The impact of the independent variable on the dependent variable is evaluated according to importance and magnitude. The results are registered at the cell marking the intersection of the column and row of the matrix arrangement (Kolhman, 1997). Each cell of the matrix is divided in two segments by a diagonal line. Impact values are recorded on the upper left corner and importance values in the lower right corner (cited by Nava from Conesa, 1995). Values of importance and magnitude are assigned by the researchers in a subjective manner using a scale from one to ten (cited by Nava from GTZ and IICA, 1996). One represents minimum impact and significance. Ten represents maximum values. In Leopold's method, zero is not a valid value.

The Leopold's Matrix method has important limitations, as a research tool, in that it is qualitative and subjective. It depends on the personal appreciation of the evaluators and thus has a reduced replicability. However, it has proven to be very useful in preliminary analysis and to identify problems that require a more rigorous analysis (cited by Nava from GTZ and IICA, 1996)

This dissertation adopts and modifies a method similar to Leopold's Matrix to measure the impact of agricultural practices on sustainability. An analysis to determine the degree of sustainability has two additional degrees of complexity more than does the environmental impact analysis -- in addition to environmental impact, it considers social and economic impacts.

As in environmental impact analysis, sustainability has many independent variables, which together determine the final effect or outcome (dependent variable) of any action. The first task is to determine the most important and relevant dependent variables using a systematic method that can be replicated with reasonable ease.

Veroutis and Aelion (1996) developed a system to compare criteria and assign levels of relative importance by using an Analytical Hierarchy Process (AHP). This process is defined by them (1996, p. 63) as

> *"a multicriteria decision-making methodology that enables consideration of extensive sets of dissimilar qualitative and quantitative criteria in making a decision".*

They further state that

> *"the methodology juxtaposes the qualities and features of the options against the relative importance of the evaluation criteria to derive an aggregated measure of performance. This analysis is based on a rational (and scientifically defensible) mathematical algorithm, thereby adding credibility to the ranking... AHP is based on the concept that when a fundamental metric is unavailable, assigning relative importance can be done much more accurately and reliably by using comparisons among competing issues rather than by using an arbitrary metric scale."*

As a result, a pairwise matrix comparing decision criteria is developed which Veroutis and Aelion call a "Criteria Mapping Matrix". In this matrix a list of dependent variables is established. These variables are listed in the horizontal and vertical axis. Each variable is compared to all the others and relative importance is judged. Veroutis and Aelion (1996) suggest a fundamental scale of importance starting with equal importance, which is given a value of 1, and ending with a 9 indicating extreme importance. Summing each row tabulates the matrix. Then, the totals of each row (last column) are added. Relative importance weights (%) are assigned by dividing the sum of each row by the sum of the totals.

The next task is to identify actions or methods of doing different tasks (independent variables) and determining the impact they have on the sustainability criteria (dependent variables). Some actions will enhance sustainability and some will have a detrimental impact. A fundamental scale of values to assess impact, similar to the one used in the "Criteria Mapping Matrix", must be devised to avoid positive and negative signs in impact valuing.

The final step is to set an optimal standard of sustainability and to compare agricultural practices to this standard. Allenby (1996, p. 77) developed a matrix analysis system "to bridge the gap between the doable and the optimal" to analyze materials for the design of products using the "Design for the Environment Approach" (DFE). Important criteria, which he calls elements (dependent variables) are identified and arranged in the horizontal axis of the matrix. Optimal conditions are identified for each element and a "Matrix Element

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Checklist" is developed that asks the appropriate questions to determined if the optimal condition is met. The different life cycle processes are identified and recorded in the vertical axis. Each material chosen for evaluation is tested at each level of the life cycle by proceeding through the Matrix Element Checklist.

An analogous procedure can be developed for agricultural production. The elements, in this case, are the sustainability criteria, the levels in the life cycle are the different components of the banana production system, and the different methods and technologies in the production process substitute the materials tested. Optimal conditions are defined to minimize negative impact on sustainability. A Matrix Element Checklist is developed to ask the appropriate questions and determine the degree of optimal compliance. Values for compliance of each method can be compared to the optimum values. Ideal compliance can be assigned a value of one; and acceptable compliance a value of 0.6. In the AHP method, no compliance can be assigned a zero.

Since the relative weights of importance of the dependent variables were previously determined, the sustainability evaluation matrix is simplified. The assigned compliance value of each independent variable is multiplied by the relative weight of each dependent variable. The resulting value is a coefficient of impact. The sum of the coefficients of impact is a measure of degree of sustainability that can be defined as a sustainability index.

This dissertation will measure the degree of sustainability for the best available practices in the case of world class banana production and will compare these values to other suggested methods of production.

1.5 The researchable questions, problem and search for solutions

The overriding researchable question is -- is it possible to attain a sustainable production system of world-class bananas by modifying the conventional production technology presently used in Costa Rica without significantly changing the market component? This dissertation assumes the affirmative. However, it is important to recognize that some experts believe that no monoculture system can be sustainable. More optimistic experts are convinced that technology can only help approximate sustainability; few accept that a truely sustainable system can be attained; and many believe that the market must suffer considerable modification before sustainability in production can be achieved.

The problem is that there is no clear definition of what constitutes a sustainable production system or a systematic method of evaluation. EARTH (Escuela de Agricultura de la Regi6n Tropical Húmeda)[8] owns a state-of-the-art

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[8] Escuela de Agricultura de la Regi6n Tropical Húmeda (EARTH) translates into English as the College of Agriculture of the Humid Tropical Region. EARTH is a non-profit, private, international university dedicated to education in agricultural science and natural resources, contributing to sustainable development of the humid tropics. It is located in the district of Guácimo, province of Lim6n, Costa Rica. This location is immersed in the major banana producing region of the country. EARTH College owns and operates a large commercial banana plantation (283 Ha.) that offers a unique opportunity for the search, application and verification of new and appropriate knowledge. Beginning in

banana plantation that produces world-class bananas. It uses improved technologies that are guided towards sustainable production, and has earned the ECO-OK seal of the Rainforest Alliance. However, the faculty of the College feels that it falls short of the ideal situation. Other plantations, some which also have the ECO-OK seal, have experimented with different practices that apparently improve the conventional technology, but there is no consensus of the experts to what constitutes a sustainable plantation, what the best available practices to achieve sustainability are, or what parameters should be used to judge the degree of sustainability. It follows that there is no existing plantation in Costa Rica that is using a farming system that is universally accepted as a state of the art sustainable production system.

Considering the previous discussion, the dissertation will ask the following questions:

- What is a working definition of sustainable banana production?
- Is it possible to construct a systems model of world-class banana production in Costa Rica at three levels of ecological organization that adequately takes into account the ecological, social and economic components, their interactions, and the inputs and outputs of the system?
- Using the system model, can a suitable quantitative measuring method be devised to evaluate and relate these effects to the normative philosophy of sustainability, and can appropriate quantitative ordinal sustainability indexes be developed to evaluate banana production processes?
- Can the system model help in answering the following questions?

1991, EARTH College pioneered an effort to identify and solve the problems of banana production through a waste management project financed by the W. K. Kellogg Foundation. Consequently, waste reduction and management has been vastly improved, reforestation of rivers banks completed, end of pipe treatment systems implemented to assure water quality, agrochemical risk to humans decreased, and understanding of the problems enhanced.

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- Is the current banana production in Costa Rica sustainable?
- If not, what changes can be implemented to improve sustainability?
- What are the effects on the ecosystem of proposed changes?
- Which proposed changes contribute the most to sustainable production?
- Can a sustainable production system be implemented without changes to the market structure?
- What bundle of technologies gives the greatest effect in seeking sustainable banana production? Can these best available practices be used as a base datum for comparison?
- Is it necessary to change the market structure to implement new and appropriate technologies?

The following tasks are proposed to answer these questions:

1. Formulate a theoretical definition for sustainable production of world-class bananas acceptable to a panel of leading experts in the field and representatives of the different sectors of the banana business (stakeholders).
2. Use a systems model to recognize cause and effect relationships and typify independent, dependent and control variables.
3. Arrange these variables in a matrix system.
4. Choose a reduced set of dependent variables to monitor according to degree of importance based on value judgment by a panel of experts.
5. Identify a group of sustainability performance indicators (SPI) to measure each dependent variable chosen, aggregate them when possible, and set minimum acceptable criteria.
6. Recognize practices that have demonstrated merit (independent variables) and choose a package of best available practices through consultation with stakeholders
7. Test the resulting bundle of best available practices against the minimum criteria, and verify the hypothesis by judging the degree of compliance with minimum acceptable SPI criteria.
8. Identify deficiencies that merit further inquiry.

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Consensus on a definition for sustainable production of bananas and choice of monitoring variables will be pursued through personal interviews with a select group of experts. The best available practices will be identified through personal interviews with specialist of the following aspects of the production system - environment, social and economy aspects. Details for each task will be outlined in Chapter 3 - Methods. The desired result is a verifiable and replicable method able to generate useful information for decision makers. This information should signal compliance or point out areas that require the allocation of resources for further development.

1.6 Statement of hypothesis

The hypotheses are as follows:

Hypothesis A

H_0: The Conventional Production Practices (CPP) are environmentally, socially and economically sustainable.

H_1: The CPP are not environmentally, socially and economically sustainable.

Hypothesis B

H_0: The Sugested Production Practices (SPP) are environmentally, socially and economically sustainable.

H_1: The SPP are not environmentally, socially and economically sustainable.

The independent variables reflect new clean and appropriate technologies identified as the best available practices that the producer can introduce to the production system, and the dependent variables reflect the causal effects on inputs and outputs by modifications in the system. The world-class standards for fresh fruits and the market structure are the control variables since they are beyond the producer's dominion. The analysis tool is a systems model of a banana plantation, a theoretical definition of sustainable banana production, and a matrix analysis of measurable effect indicators.

1.7 Justification and relevance

The problems of banana production for the export market have important repercussions, which transcend political frontiers. Bananas are produced in most of the tropical countries of the world, and it is a basic food source for the people of these countries. The tropics represent about 20% of the earth's land mass. Approximately 45% of this area is located in Latin America, 30% in Africa, and 25% in Asia. The region is home to two billion people distributed in approximately sixty countries. Banana varieties used for the export market are particularly well adapted to the humid tropic ecosystem, often referred to as tropical rainforest. About 7% of the earth's land surface fits the tropical rainforest ecosystem's characteristics. The experts believed that these areas are critical and very sensitive because they harbor more than half of the world's plant and animal species (CSA, 1993). Due to climate and edaphic conditions, the tropical rainforest ecosystems are very fragile and susceptible to disturbance by human activity.

Brazil and India are the largest producers of bananas in the world, however they produce essentially for internal consumption. Since this research is lim

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is limited to the study of the problems caused by the conventional technology used to produce world-class bananas, fruit from Brazil and India are disregarded. The Philippines and Ecuador are the third and fourth largest producers in the world respectively, however the Philippines exports less than half of its production while Ecuador exports 90.2% of its production, and is the largest exporter of bananas in the world (Soto, 1992).

Costa Rica is the second largest exporter supplying 15% of the total export market and is the focus of this study. This country was chosen as a representative case because of high productivity, the use of advanced industrialized agricultural technologies, a marked and growing interest by its citizens for environmental integrity, availability of data, and logistic advantages for conducting the research.

EARTH's banana farm[9] is located in the center of the banana producing region of Costa Rica. The climatic and edaphic conditions are not the best or worst in this region and the production is slightly above the country's average. EARTH's plantation is divided into five distinct projects serviced by one packing plant. The smallest project is 40 hectares, the largest 140 hectares, and all are connected to the packing plant by a cable transportation system. The oldest project has been farmed continuously for the past 30 years and the newest started production in the last five years.

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In Costa Rica, the smallest plantation growing bananas for export has 40 hectares and the majority of the farms range between 100 and 300 hectares. The oldest farms have been in production in excess of 100 years, most have been in production for at least 10 years, and the newest have recently started production. Therefore, EARTH's commercial farm is representative of typical world-class banana plantation for Costa Rica. It is distinguished from the others because of its continuous effort to identify and employ the best available people and environmental friendly technologies.

This study emphasizes the best available practices that are controlled by the producer, and recognizes the importance of externally controlled variables, such as markets and trade policies, that have a colossal effect on sustainable production but are beyond the producer's control. The United States is the largest importer of fresh bananas (32%), followed by Germany (13%) and Japan (8.7%). The United States and Germany are primarily supplied from Latin American producers while Japan is supplied by the Philippines (Soto, 1992). According to 1991 statistics, Costa Rica exported 51.8% of its bananas to the United States, and 49.2% to Europe (Sanchez and Barrientos, 1992). Because of their predominance as customers, the study is limited to the structure and standards of these two markets.

World-class banana production is a critical element of Costa Rica's economy. This agroindustry is the most important generator of foreign currency. It is an important source of jobs and opportunities for related businesses, and supplies many services to the communities. These bountiful benefits to Costa Rica are reciprocated by immense corresponding costs.

The literature reveals sufficient information on biological and agricultural aspects of banana production. However, there is a lack of published information on environmental and ecological aspects. Daniel Janzen (1983, p. 77) confirms this situation, stating that –

> *"Though extensive in occurrence, the banana plantation as an ecological habitat has been little studied."*

This lack of information points to an opportunity for pertinent and much needed research and peer reviewed publication, which can be generally accepted as trustworthy. It confirms the need for verification of suppositions and rejection of unsupported declarations that the effects of banana production on the environment are not as inoffensive as producers proclaim, or as severe as environmental activists portray them.

As stated in previous sections, there are many definitions of sustainability, yet there is not one that is universally accepted. There are fewer definitions of sustainable agricultural development, but once again, there is no consensus (del Camino and Muller, 1993). Finally, the literature does not provide a definition of sustainable production of bananas for the export market. Many experts believe that a universally accepted definition is detrimental and that one should be derived to fit each case and purpose. Nevertheless, the Instituto Interamericano de Cooperación Agrícola (IICA, 1991) manifests that the lack of a precise and objective definition is the first difficulty to overcome in defining strategies for su

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sustainable development. It also recognizes the importance of identifying indicators capable of measuring beyond economic growth.

A prerequisite to solving the problems of the banana export industry, it is necessary to elaborate a united and integrated strategic plan including the development of a matrix to measure economic, environmental and social impact. However, before a matrix can be developed, it is imperative to define what constitutes sustainable production of bananas and what the objectives and principles are that must guide this activity.

Notwithstanding the lack of an objective and clear definition of sustainable development, the literature revealed a consensus that three conditions must be achieved for sustainable development: 1) economic feasibility, 2) environmental soundness and 3) social appropriateness and equity. According to the opinion of many experts, present world-class banana production practices in Costa Rica fail all three requirements for the reasons that will be analyzed in detail in Chapter 2.

The problem is complex and so are its causes.[10] The causes can be divided into the following five categories and ranked by their degree of difficulty in the following manner: 1) Cultural and Social, 2) Political, 3) Market, 4) Financial,

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10 A detailed analysis of the causes was conducted by the author through a series of workshops with EARTH's faculty and fourth year students. The typical forth-year student has had sufficient theoretical courses and practical experiences to express a very educated opinion.

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and 5) Technical.[11] Due to the complexity of the problem and causes, the pertinent question is how to analyze proposed changes in a holistic manner so that changes introduced in one component do not create even greater problems in other components.

A systems approach is a proven tool that facilitates holistic analysis by characterizing the nature of the system under study in such a way that the decision making can take place in a logical and coherent fashion. The first step is to define an appropriate temporal and spatial scale, or levels of organization. The larger the limits, the more information is available and the larger the need for aggregation. The resulting model is therefore the less powerful and sensitive. Conversely, if the scale is too small, the model becomes insensitive to interaction with higher levels of organization (del Camino and Muller, 1993). The appropriate level of analysis for this dissertation is the banana plantation. Nonetheless, it recognizes interactions with global, regional, national, local and micro scales. The system's model used serves as a map of components, actions and reaction, and inputs and outputs.

The long-term goal is to develop an integrated set of guiding principles and measurement system that can steer the industry toward sustainable

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[11] Note that the technical problems and causes are the least difficult to solve. The faculty and the students interviewed all felt that the technology is available if the other 4 problems are solved.

development. The short-term goal is to identify the best available practices for immediate implementation by the producers.

1.8 Conditions outside the control of the producers that have a bearing on change

The banana export industry was born approximately 120 years ago with the development of transnational marketing firms (Soto, 1992). History shows that these firms were not kind guests of producing countries or good stewards of the environment. It is a past that the people of Costa Rica wish to forget, but should not forget. The important issue is to learn from the past, analyze the present and find ways to improve the future.

The magnitude of the banana industry is very large and complex. Considering all the different components, it is a multi-national and multi-billion dollar industry (The Packer, 1994). Consequently, it is very attractive to large transnational firms because it is an opportunity to create a vertically integrated system capturing many profit centers. These include production, transportation, and marketing. It easier for small local firms to master the production component of the equation, however transportation and marketing is a superior challenge. Because markets demand quality, service and price, and their territorial limit is the world, they require a sophisticated and large support infrastructure. This translates into large investments, economy of scale and experience. Therefore, giant transnational firms control the market.

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Controlling the market means controlling quality standards, quantity and price. In the consumption end of the equation, it is accomplished through price and brand recognition. In the production side, there is no choice. Transnationals buy from whomever they choose at the price they set. When governments of producing nations intervene, transnationals use powerful politicians to exert pressure through loss of most favorable nation status, or by blocking bilateral aid and multilateral loans.

Transnational firms have primarily three home origins - United States, Europe, and Latin America. However, their ownership and legal structure is not necessarily tied to one country. The order in which origin was presented reflects the importance, experience and market share. At the present time, there is a struggle between Europe and the United States to change that order and home governments adopt policies which favor their own transnationals at the expense of economic, social and environmental impacts in the less powerful producing countries. As a producing nation, Costa Rica has suffered, but it has learned to maneuver and take advantage of competition among these firms to make substantial changes.

The model that is being proposed, identifies the links and measures the effects of marketing policy changes. It can be used to identify the missing direct feedback loops between consumers and producers. Through this connection, the producer can educate the consumer, create market niches, and generate opportunities to sell the product of new non-conventional technologies.

1.9 Conclusion

The following summary scans the information presented in this chapter: According to the opinion of many experts current banana production technology is not sustainable because it fails the three basic conditions: 1) economic feasibility, 2) environmental soundness, and 3) social appropriateness and justice. There is an urgent need to verify this opinion. If true there is an urgent need for change and improvement. However, there is no universally acceptable normative philosophy that guides changes towards sustainability. Furthermore, there is no systematic method that traces and measures effects through the entire system. This is important because change in one component will automatically affect all other connected components of the system. Positive change in one component may bring disaster in other components. In conclusion, there is a need for a systematic method capable of identifying and evaluating the effects of changes and of determining their contribution to sustainable development.

The next step in this dissertation is to place the problem within its environment. Chapter 2 presents the banana case noting problems, symptoms and causes, and suggesting solutions. Then, the details of the proposed method will be presented in Chapter 3. Chapter 4 will bring together and analyze the results. Finally Chapter 5 will present the findings, conclusions and recommendations.

The previous discussion has confirmed the value of developing a normative philosophy, but it has highlighted the complexity of the proposed hypothesis. It has recognized that the producer controls not all elements of the banana industry. It has alerted the author to the need for setting realistic boundaries to this research. It has reminded the author that he has an immediate task to accomplish and that he can not tackle the entire problem. In essence, this dissertation marks the beginning of a permanent and dynamic search for a vision for the banana industry of Costa Rica as it tries to develop a sustainable system of production with the purpose of building a new and better world, one that offers greater opportunities for a better quality of life for present and future generations.

Chapter 2

PROBLEM FOCUSED LITERATURE REVIEW

2.1 Introduction

This chapter is a revised and up-dated version of the article titled

"A Systems Approach to Evaluating and Managing the Environmental Impact of Banana Production in Costa Rica"

written by the author of this dissertation and Dr. Scott Witter and published in AMBIO in May 1996. The objective of this chapter is to review the available literature in order to appraise present conditions in the world-class banana production industry, identify the major problems, and to seek alternative solutions to improve the sustainable performance of the banana production processes.

An important part of Costa Rica's 20th century agricultural growth and development has been the increase in banana production and economic growth without regard to ecosystem integrity. Human wants and needs have prevailed, and natural resources have proved to be exhaustible. Furthermore, the allocation of the benefits from the exploitation of the natural resource base has not always been equitable among Costa Ricans or between transnational companies who mine the country's resources.

Ecologists, especially non–Costa Rican ones, want to adopt John Muir's (early American ecologist) approach to Costa Rica's natural resources, conserving and preserving the abundant biodiversity of flora and fauna for future generations at all costs. Yet, if national and transnational companies that degrade the environment are too restricted by environmental regulations and move to a country with fewer restrictions, as they have throughout history (Casey Gaspar, 1979), it is only Costa Ricans who will suffer. A balance must be sought between unsafe resource exploitation and needed economic growth.

Within Costa Rica and throughout the humid tropics, the concept of sustainable development is gaining momentum as countries face the reality that most renewable natural resources are quite limited (Brown, 1993; CSA, 1993; Edwards, Grove, Harwood and Pierce, 1993; MIRENEM, 1992; Prance, 1989). The necessity for long-term planning is being discussed by all of the banana sector stakeholders.

This chapter presents an overview of banana production in Costa Rica based on the importance of bananas as an export crop and the environmental impacts associated with their production. The author takes a systems approach to identifying problems and suggesting ways that will help to balance the economic exploitation of Costa Rica's natural resources with long-term environmental integrity.

2.2 Systems Approach

A system is defined as

> *"Any phenomenon, either structural or functional, having at least two separable components and some interaction between these components (Churchman, 1968)."*

A systems approach is a tool that facilitates comprehensive analysis by considering the nature of the system under study on many levels and in such a way that the decision making can take place in a logical and coherent fashion, thus minimizing the occurrence of "the fallacies of narrow-minded thinking" (Churchman, 1968).

The first step is to define the spatial and temporal boundaries of the system under consideration. The system is broken down into components and functions that control exchange among components and that are interrelated by cause and effect, stimulus and response. This process helps identify internal and external causes and effects, inputs and outputs, and the appropriate opportunities for action.

At least in theory, the consequences - that is, the reaction of every action -- can be traced through the system and a resulting behavior predicted. On the basis of this prediction, adjustments can be made to improve the system and/or components and standards may be modified to fit reality. This process is referred to as modeling, and its purpose is to help with conceptualizing, organizing, and communicating complicated phenomena (Hall, Cleveland and Kaufmann, 1977). Modeling is often accompanied by an extensive effort to assign mathematical formulas to quantify stimulus and response.

At the beginning of a systems analysis, however, mathematical modeling is often unreliable. Models depend on the volume and precision of existing data and especially on the quality of the underlying concepts. When all are poor, as they frequently are because of collection techniques and a lack of knowledge of the system itself, the model may have little bearing on the existing situation. It is often far better to start at the beginning and develop a conceptual/descriptive model followed by a diagrammatic or flowchart depicting the system (Hall and Day, 1977). This is then followed by the development of an appropriate mathematical model which can be converted to a computer program that allows for an analytical quantification and/or simulation of the system (Hall and Day, 1977). The objective of this dissertation is to develop a mathematical model. This model organizes data gathered from a panel of expert assigning weights to the interactions between components of the system. It also allows for the experts to rate production practices based on their impact on the environment, society and the economy. The result is a Sustainable Performance Index that assigns a grade according to the degree of sustainability of alternative production practices. Such analysis, by its nature, requires interdisciplinary thinking and action.

2.3 Costa Rica

Costa Rica's climate is tropical and subtropical, and the interception of the trade winds by the central mountain range produces large quantities of precipitation along the northeast slopes with annual rainfall in excess of 1500 to 4000 mm. Large-volume, rapidly flowing rivers originating in the mountains chisel high-mineral volcanic rock sediments from the mountain slopes and deposit them in the lowlands. Some of these sediments are ideally suited for high-production banana plantations. The Caribbean coastal plains of Costa Rica possess bountiful areas with soils that possess these characteristics and account for 98 percent of the total area planted (Figure 4) (Sanchez and Barrientos, 1992).

Commercial banana plantations are generally located at altitudes below 200 meters with annual rainfall levels below 4000 mm and are usually on sites with little or no slope. They require a complex drainage system to funnel excess water from the site (Lauer, 1989).

Bananas produced for the international markets can only be commercially produced on the best soils.

> *"They require flat terrain, deep (no less than 1.20 meters), good structure, and well-drained soils (humid but not saturated) with a high balance of nutrients (especially potassium) and a pH between 6 and 7.5" (Soto, 1992).*

To maintain commercial production rates, it is necessary to add significant amounts of fertilizer to the soil throughout the entire growth cycle.

Costa Rica's Banana Producing Regions

Figure 4 - Map of Costa Rica: Banana Growing Region & EARTH College Location

2.4 Banana Production in Costa Rica

Minor Keith started the first commercial banana plantation in Costa Rica in 1872, in Zent Valley. By 1879, Costa Rica was exporting bananas regularly to the United States (Soto, 1992). It was at this time that the first transnational companies emerged, attracted by generous land concessions, tax exonerations, and other government incentives.

The Boston Fruit Company and Minor Keith joined forces in 1899, forming the United Fruit Company. This partnership helped develop a worldwide market for bananas, and began the dominance of United Fruit over Central American banana production. By 1920, United Fruit was well established in most of the Central American countries. And by 1930, United Fruit owned about 4 percent of the total territory of Honduras, Guatemala, Costa Rica, and Panama. The company's political influence brought about the humiliating characterization of these countries as `Banana Republics', a perception still held by much of the world.

Unregulated exploitation strategies of maximum production with minimum input typified early transnational operations. Eventually, of course, production efficiency dropped and, when the Panama banana disease forced production down further, United Fruit began abandoning plantations along the Atlantic coast of Costa Rica and transferring operations to the Pacific coast (Casey Gaspar, 1979; Kepner, 1935; McCann, 1976).

By 1956, the government of Costa Rica had become concerned about the growing number of banana plantations abandoned due to the `Panama disease', inefficient production technologies, and the careless use of the country's natural resources by the United Fruit Company. The need for a shift in the banana production process was apparent, and so began the second era of banana production in Costa Rica. In an attempt to offset the downward trends, the government recruited Standard Fruit Company, which not only established its own plantations but also began purchasing fruit from Costa Rican producers (Bourgois, 1989; McCann, 1976).

Standard Fruit introduced the Valery banana clone, which was resistant to the Panama disease, produced increased yields, had favorable packing and shipping characteristics, and generated a product that was acceptable to international consumers. This transformation was not without side effects, however. The Valery banana required considerable chemical intervention as well as intensive field and processing management (i.e., plastic bags, special packaging, and atmospheric controls during shipment). Therefore, while the addition of Standard Fruit introduced competition to the banana economy, it changed banana production from a low chemical input system to one dependent on large volumes of pesticides, herbicides, and fertilizers. While government regulates the chemicals that can be used in Costa Rica, the transnational companies have traditionally determined the volume, kinds, and frequency of chemical use in banana production.

The nationalization of the banana market in Ecuador in 1965 resulted in the migration of other transnational companies to Costa Rica, further intensifying competition and the need to produce more per hectare (Soto, 1992). A decade later, United Fruit was reorganized, becoming the United Brands Company, and introduced the Chiquita label to Costa Rica. In the 1980s, United Brands closed its operations on the Pacific coast of Costa Rica and returned to the Atlantic under the name of Compania Bananera del Atlantico Ltda (COBAL). COBAL aggressively expanded banana production along the Atlantic and now is the second largest producer in the country. Today, the transnational companies produce 40 percent of the total harvest and control another 58 percent of the country's banana exports. Although Costa Rican-owned companies produce 60 percent of the bananas exported, the majority of the companies follow transnational-dictated production practices and quality standards, and the bananas are exported under the control of the transnationals.

Costa Rica, as a national policy and by the actions of many individuals and companies, has chosen to generate much of the revenues needed for foreign exchange through growing traditional cash crops for export.[12] The agricultural sector of Costa Rica contributed 19.6 percent of the gross national

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12 The World Resource Institute (Thrupp, 1994) defines nontraditional exports as "various agricultural products destined for export markets, other than coffee, bananas, cotton, beef, and sugarcane. A product is considered nontraditional if it: 1) in not produced in the particular country before, such as broccoli in Ecuador; 2) was traditionally produced for domestic consumption but is now exported; or 3) is a traditional product but is now exported in a new market." As a corollary, coffee, bananas, cotton, beef, and sugarcane are defined as traditional export crops.

product and banana production accounts for almost 30 percent of the sector's total receipts (IUCN, 1991). Since 1990, no other export commodity surpasses the contribution of bananas to foreign currency income in Costa Rica. Based on the 1994 statistics, bananas were the most important crop generating $552.3 million (dollars US), followed by coffee at $300.2 million, meat at $51.3 million and sugar at $32.1 million (Banco Central de Costa Rica, 1995). In 1994, the banana export revenues represented 25% of all export revenues. In 1995, revenues from banana exports rose to $649 million and the Government of Costa Rica collected a total of $44.3 million in export taxes (Paez and Zuñiga, 1996). It is unclear how much of the banana export revenue actually remains in the hands of the Costa Rican producers; however, it is apparent that the price paid to the producer accounts for only about 25 percent of the consumers' price.

The economic impact of this production on Costa Rica's regional economy is also quite significant. It takes 0.89 workers per hectare per year to manage the plantation. Approximately 43,000 Costa Ricans are directly dependent on banana production for their livelihood, and this does not include part-time employment on plantations or the domestic service industries that support the banana producers (Foro Industrial, 1994).

2.5 Systems Analysis of Banana Production

The ecosystem provides humans with the habitat in which they live and the resources necessary to satisfy their needs and expectations. Development of resources requires change. If managed properly, the change provides positive benefits; if not, the opposite is true (Axinn, 1988; Colby, 1990).

There are five basic paradigms for the management of the relationship between humans and nature: deep ecology, frontier economics (e.g., the exploitative practices of the transnational companies), environmental protection, resource management, and ecodevelopment (19). Each has both positive and negative sides, but ecodevelopment appears to offer the best chance for long-term sustainability (Colby, 1990). Ecodevelopment attempts to restructure the relationship between production and the environment.

> *"It sees most development activity as a form of management of this relationship; environmental management, economic development, and socio-ecological development might virtually become semantic distinctions for the same subject: the integrated convolution of conscious civilization and nature" (Colby, 1990).*

The ecodevelopment approach is used in this paper to seek a balance between the need to produce high quality bananas to generate foreign currency and the need to protect Costa Rica's environment. The following discussion goes through the conceptual, diagrammatic, and mathematical systems modeling processes.

Figures 13 and 14 in Appendix A are conceptual diagrammatic models of a banana production system in Costa Rica. Three major components within the ecosystem are identified: the plantation, the packing plant, and the housing units. Every input has an influence on the output and eventually on the banana market, if the system is maintained through a continuous cycle. The output of bananas requires a series of inputs. It is necessary to remember that besides the desired usable output, the fruit, there are output wastes generated that must be managed if the banana production system is to be sustainable.

Perhaps the most complex and least-understood component of the system, outside of the plantation manager, is the agroecosystem itself. To understand it, it is useful to redefine the boundaries of the system to a smaller scale (Figure 14 in Appendix A). There are two types of dynamics present in the system: those that can be controlled by human actions, and those that are controlled by nature. The dynamics controlled by humans are shown outside the rectangles and are the focus of this paper. The human and natural factors, however, are not independent of each other and any human action in the system has an impact on the natural processes.

Harvesting a crop removes nutrients from the system (CSA, 1993; Cunningham and Saigo, 1990; Nebel, 1990). High-level production systems, like bananas, extract large quantities of nutrients and water. Soil nutrients cannot be replaced by mineralization of the parent soil or natural fertilization via decomposition at the same rate as they are removed by harvest, and must be augmented with commercial inputs. Water losses from evapotranspiration are significant in the amount of energy required, but the water loss itself is replenished by the large amounts of precipitation occurring yearly in the banana production region.

Monoculture production systems, like bananas, increase the concentration of food sources for other organisms (i.e., insects, bacteria, and fungi). As a result of an abundant food supply, such organisms multiply readily and begin to compete with humans for the harvest. Consequently, high-production systems require high levels of inputs, not only to produce a product, but also to eliminate competing organisms (Cunningham and Saigo, 1990; Nebel, 1990; Peakall, 1992).

Fertilizers, herbicides, fungicides, and insecticides are not entirely used by the plants nor are they retained within the plantation, leaving the system as liquid leachates, surface runoff, erosion, or gases. These byproducts often have a dramatic impact on the environment, especially through surface water systems (Figure 14 in Appendix A). In addition, pests and soil organisms appear to adjust to biocides by developing a resistance to the chemicals (Peakall, 1992; McKenry, 1991). This generates a positive feedback by creating the need for higher quantities of inputs and new chemicals to maintain production levels.

Unfortunately, humans do not readily develop resistance to these chemicals and the adverse effects can be severe, for example, cancers, sterility, and genetic malformations (Ragsdale and Sister, 1991). Epidemiological data regarding banana production in Costa Rica have shown more than 10 percent higher instances of sterility and damage to kidneys, liver, brain, nervous systems, lungs, heart, eyes, blood, skin, metabolism, and the overall immune system in people associated with banana production as compared to the general population (Hilje, Castillo, Thrumpp and Wesseling, 1992). These side effects are hard to account for in economic evaluations and are not internalized as a cost of banana production systems.

A list of human-controlled inputs has been developed from the agroecosystem model. The inputs and outputs at the plantation and packing plant, plus the type of residual and its treatment components, are listed in Table 1 and 2. Considering information gathered from Costa Rican producers and the management experiences gained at the EARTH College's plantation in Limon, indices have been developed to quantify the residual materials entering the ecosystem (Table 3). In some cases, calculations using these indices by area and by unit of production have resulted in different estimates of the amount of waste generated. In these cases, the highest number is presented to represent the largest potential impact.

Table 4 summarizes the results obtained by applying the quantities reported in Table 3 to the 1995 banana export statistics. Table 4 shows that for each ton of bananas exported, 0.5 tons of waste is produced that will require onsite treatment.

In order to grasp the magnitude of this waste problem, it is useful to contrast banana production waste to the total waste generated in Costa Rica (all urban sources found in the waste stream combined) on a daily basis. A study performed in 1990 (Government of Costa Rica and GTZ, 1990) found that the total amount of waste generated per day in Costa Rica is 11,764 tons. The total waste generated per day by banana production requiring onsite treatment is 2 626 tons or 22 percent of the total waste generated in the country (Table 4).

Table 1 - Inputs vs. residuals for the plantation in a banana production system

System Component	Inputs	Residual Materials	Type of Residual	Treatment
Plantation	Agrochemicals · Fungicides · Nematicides · Herbicides · Fertilizers	Chemicals · Liquids - Leachates - Runoff · Gases · Solids - Sediments	Non-point source Degradable	Type of Treatment · Reduction · Substitution
	Agrochemical Containers	Containers · Solid waste - Paper bags - Cardboard boxes - Plastic bags - Plastic jugs - Metal drums · Rinse water	Point source Non-degradable	Type of treatment · Solid waste - Reduction - Triple rinse - Recycling - Incineration - Landfill ash · Rinse water - Containment - Neutralization - Biodegradation - Oxidation - Evaporation
	Plastics · Bags · Twine	Plastics · Polypropylene - twine · Polyethylene - bag	Point source	Type of treatment · Reduction · Collection · Reuse · Recycling · Incineration · Landfill ash

Table 2 - Inputs vs. residuals for the packing plant in a banana production system

System Component	Inputs	Residual Materials	Type of Residual	Treatment
Packing Plant	· Fruit · Cardboard Boxes · Pallets · Plastic Straps · Fungicide · Plastic Bags	· Cardboard boxes · Pallets · Plastic straps · Plastic bags · Spoiled fruit · Peels	Point source Degradable & non-degradable	(*) Exit system and must be treated at market destination.
	Fruit raceme	Substandard bananas	Point source Degradable	· Reduction · Sale in local market · Value added by-product · Animal feed · Compost · Biogas · Landfill
	Fruit raceme	Banana flowers	Point source Degradable	· Return to plantation
	Fruit raceme	Raceme's stems	Point source Degradable	· Return to plantation · Value added by-product - Fiber - Paper - Humic acid · Compost · Landfill
	Plastic Bags	Plastic bags	Point source non-degradable	Plastic - Same as point 3
	· Fungicide · Coagulants	Agrochemicals	Point source Degradable	Agrochemicals · Reduction · Substitution
	Fruit	Organic materials · Crowns · Latex	Point source Degradable	· Coagulation · Filtration · Return to plantation
	Water	Residual water	Point source Degradable	Water · Primary treatment · Recycle · Secondary treatment · Return to environment

Table 3 - Indices and information needed to calculate waste generation in banana production

	Description	Indices	Waste generated in tons per year
1.	% Fruit exported	80%	
2.	% Fruit rejected	20%	
3.	Weight per box in KG.	18.14	
4.	Boxes exported in 1995	112 Million	
5.	Tons exported = (4*3/1000)	2.03 Million	
6.	Tons produced = (5/1)	2.53 Million	
7.	Wasted substandard fruit = (6*2)		508,000
8.	Boxes per raceme	1.10	
9.	Average weight per raceme in KG.	27.21	
10.	No. racemes produced = (4*8/1)	154 Million	
11.	No. of racemes per tree	1	
12.	Average weight of raceme's stem in KG.	2.5 kg.	
13.	Waste stems (12*10/1000)		385,000
14.	Area under production	52,166	
15.	Twine per raceme in KG. Ref: McNeel International Corp. (Personal letter March 10, 1997)	0.0322	
16.	Twine residuals = (10*15)		4,960
17.	Average weight of plastic bag in KG. Ref: McNeel International Corp. 1997	0.038	
18.	Plastic bag waste		5,850
19.	KG./HA./Year plastic packing material	65.00	
20.	Plastic packing material = (14*19/1000)		3,390
21.	Weight in KG. of crowns and flowers per raceme	0.35	
22.	Crowns and flowers = (21*10/1000)		53,900

Table 4 - Waste Generated in Banana Production

DESCRIPTION	TONS OF WASTE GENERATED PER YEAR	TONS OF WASTE PER 100 TON EXPORTED
Non-Degradable Waste		
Twine	4,960	
Plastic Bags	5,850	
Agrochemical Containers (*)	782	
Total Non-Degradable	11,592	0.57
Degradable Waste		
Crown and Flowers	53,900	
Raceme's Stems	385,000	
Fruit Rejected	508,000	
Sub-Total	946,900	46.65
Total Waste Requiring Treatment Within System's Limits	958,492	47.22
Bananas Exported 1994 in Tons	2,030,000	
Waste Requiring Treatment Within System's Limits per Day	2,626	
Total Waste Per Day Generated in Costa Rica (**)	11,764	100

(*) McNeel International Corp. (Personal letter, March 10,1995

(**)National Program for Waste Management (1990)

2.6 Wastes and Alternatives

The first solution to waste is to reduce its quantity at each processing point. Waste products generated must be reused until all useful qualities have been recycled or made into new products. When all recycling strategies have been exhausted, the remaining waste must be disposed of via incineration and/or deposited in a properly designed and managed landfill.

Banana wastes may be broken down into five primary categories: nonpoint source residuals, point source degradable solid waste, point source liquid waste, point source nondegradable waste, and hazardous waste.

2.6.1 Nonpoint Source Residuals

The nonpoint residuals are the least understood and most difficult to treat. They are generated through the use of chemical and natural fertilizers, nematicides, fungicides, and herbicides. The only insecticide widely used is impregnated in the blue plastic bags used to cover the raceme. The chemicals most often used include (brand name): Karrax, Ranger, Roundup, Counter, Dipel, Furadan, Mocap, Rugby, Beniate, Bravo, Dithane, and Mertak. All, if used in improper concentrations or in violation of manufacture's recommendations, can cause acute oral, dermal, or inhalation poisoning of people and animals in and around the plantation (Hilje, Castillo, Thrupp, and Wesseling, 1992). The quantity of the residuals depends on the amount and frequency of application, the type of chemical, soil type, precipitation, temperature, wind velocity, location, and method of application.

Bananas are commonly fertilized with synthesized chemical nutrients. Fertilization is applied manually. There is considerable waste when chemical fertilizers are applied heavily and infrequently because the plants can not benefit from the application before much of it is washed away or dissipated. It is estimated that the harvest of 40 tons per hectare per year removes 56 kg/ha/year of nitrogen, 24 kg of phosphate, and 220 kg of potassium (Soto, 1994). However, the most common quantities applied are: 300-500 kg phosphorus, 400-700 kg potassium, 80-150 kg magnesium, with the objective of maintaining the quality and size of fruit for export (Sanchez, 1996). Therefore, the plant does not utilize a large quantity of applied fertilizer. Part of this material leaches from the soil and contaminates surface and groundwater. A portion is immobilized in the soil and a portion is volatilized. Consequently, a better practice is to apply fertilizers 14 to 22 times during the growth cycle and with a 20 to 50% reduction in the rate of application, depending on the physical and chemical properties of the soil and the nutritional state of the plants (crop logging).

Black *Sigatoka* is a major pest in banana production (Soto, 1994). Black *Sigatoka* affects the productivity of the plant and quality of the fruit, and causes premature ripening. A successful operation depends to a great extent on proficient pest control. Good cultural practices constitute the first line of defense against black *Sigatoka*. A good drainage system, sanitation measures, weed control, and monitoring of climate and the disease reduce the degree of infection and chemical use. In addition, infected leaves or parts of the leaves are removed weekly to reduce the inoculate. Dead leaves are also removed to eliminate insect habitat and protect the fruit.

However, the aggressive nature of this fungus necessitates the frequent application of fungicides to maintain productivity and quality. Fungicides to control black *Sigatoka* are applied with aerial spraying. This method constitutes a possible source of nonpoint source pollution.

The transnational grower-buyers have their own control systems. Most of these companies operate their own equipment and have their own airport facilities. Other transnational companies contract services with Independent national spraying companies and rent airport facilities.

Most independent producers cannot afford to own their own planes and operate airport facilities. Independent producers have the option of choosing the control system and the spraying company. However, the quality of the fruit is controlled by the transnationals who buy the fruit, and the quality depends to a great extent on the control of black *Sigatoka*. To avoid quality problems and to ensure a good service, many independent producers consider it more convenient to contract with the transnationals the planning and implementation of control programs for their plantations. Since the transnational grower-buyers have adequate technical support and monitoring, this arrangement helps ensure that only approved products are used for aerial spraying.

The frequency of spraying is from 28 to 45 cycles per year and represents 12 - 16% of the costs of production. The fungicides sprayed are either systemics or protectants. In recent years, the use of systemic fungicides has been reduced drastically because there are evidences that the black *Sigatoka* has developed resistance to this type of fungicide.

The products are mixed according to the purpose of the control. The principal products used are Triazoles, Benimidazoles, Mancozeb, Clorothalonill, Morfolinas and agricultural oil. Most control programs include 50 - 75% of the applications with Mancozeb. The rate of application of the systemic fungicides is approximately 100 grams of active ingredients for each 20 liters of inert liquid per hectare (PE 16, 1997).[13] The protectant fungicides require a much higher rate.

The government approves and regulates the types of chemicals that may be used for pest control. However, the "cocktails" (mixtures of chemicals) are "trade secrets" that are zealously guarded because they may provide a competitive edge among the companies.

All the fungicides used, with the exception of Calixin, are approved by the EPA and must meet strict testing guidelines for persistence and biodegradability (PE 16, 1997). Calixin is not registered with the EPA because it is not used for agriculture in the United States of America. It is registered in European countries.

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13 The information in section 2.6.1 is a compendium of information supplied by the Panel of Experts. Panel Expert (PE) 16 is referenced individually because the information was supplied verbally during the interview and latter confirmed in writing.

However, the EPA regulates residual tolerances on imported fruit, requiring that the chemicals pass a rigorous registration process including tests for toxicity and biodegradation (PE 16, 1997).

Studies performed by the chemical companies have demonstrated that approximately 20% of applied fungicides are lost to drift and do not reach the intended destination. This creates a contamination problem for the areas bordering the plantation, and the degree of importance depends on the geometric layout of the plantation, the proximity of rivers and centers of population, and the flight pattern of the cropduster. Studies conducted by the Universidad Nacional have demonstrated the presence of limited amounts of fungicides used in the control of black *Sigatoka* in waters of canals and rivers around banana plantations (Castillo, 1997).

Spray drift has become a major concern for the general public in the United State. As a result, a Spray Drift Task Force was created in 1994 which is studying mechanism to reduce this problem (Boillot, 1997). These new and improved methods will eventually reach Costa Rica and alleviate the problem.

Of the 80% of the fungicide that arrives at the intended destination, approximately 65% is deposited on the leaves. The remaining 15% passes through the canopy falls to the ground In the case of systemic fungicides, the plant absorbs the active ingredient in the first 8 hours. In the case of protectants, the fungicides generally have sticking compound incorporated in the formulated product so it adheres to the leaves. Sometimes additional gumming agents are incorporated (PE 16, 1997). However, it is highly probable in humid tropical climates that some of the fungicide is washed off the leaves by rain and falls to the plantation floor. Depending on weed and residue management practices, part of the fungicide that falls to the floor will be deposited on dead banana tissue and vegetative ground covers (weeds). The rest of the material falls on the soil (PE 16, 1997). The fungicide that falls to the ground can not be considered a total loss. It serves to neutralize the sources of inoculation that are associated with living and dead vegetative material on the plantation floor.

According to the registration test presented to EPA, the fungicides used for black *Sigatoka* control have a short life and are designed for rapid biodegradation. They are also fairly insoluble in water and have a high affinity with clay particles, so they are easily immobilized, reducing the probability of subsurface migration (PE 16, 1997).

Surface migration of the fungicide in runoff depends on the lapse of time between application and precipitation event, as well as the intensity and duration of the precipitation event. The fungicides that wash into the canals probably precipitate out of solution and bond to the sediments. Because the active ingredient has a short life and is biodegradable, fungicides that are immobilized in the sediments probably metabolize quickly (PE 16, 1997). Further study of metabolites generated from fungicides and their fate is necessary because these by-products may have a detrimental impact on the environment (Castillo, 1997).

To minimize the risks of pollution and so that the fungicide application fulfills its objective, spraying is done only when favorable climatic conditions exist. This infers that it cannot be raining, there can be no threat of imminent rain, and the temperature must be below 28-29 degrees C, the wind velocity below 4 meters per second, and the relative humidity less than 70-80%.

Precautions are taken to avoid spraying rivers or springs. Some plantations do not respect buffer zones for rivers, streams, and springs. The majority of plantations do not have buffer zones along roads. New plantations and some of the older plantations have begun to correct this problem, creating buffer zones for waterways as well as for roads.

With few exceptions, the banana companies' facilities for mixing the product and filling the airplane are located in airports and are equipped with sedimentation tanks. There are serious deficiencies in the design of most of these systems. Some airport facilities, especially those operated by transnational companies, have equipment for recycling residues and containment systems for spills, which considerably reduces the risk of contamination.

Nematodes constitute a major pest in banana (Soto, 1994). Integrated pest management practices are the first line of defense against nematodes. Nematicide applications are restricted to the areas having the probability of damage greater than an economic threshold, by means of a systemic inventory of nematode populations, percentage of living and dead roots, and the quantity of uprooted plants. Carbamates and organophosphates are applied. The majority of the chemicals used are highly toxic (Sanchez, 1996).

Carbamates and organophosphates are applied. The majority of the chemicals used are highly toxic.

Depending on the climate, the age of the plantation and the chemical product used, nematicides are applied from 2 to 3 times per year. Nematicides are applied in granular form containing 10-15% active ingredients and 85-90% inert. The average use of nematicide active ingredient is from 7 to 15 kg per hectare per year depending on the frequency and dosage applied (PE 16, 1997). The active ingredient is only released from the granules in humid conditions (Sanchez, 1996).

Strong rains, combined with bare soils and a good drainage system, increase the probability that the nematicides will migrate to water sources. However, the presence of granules outside the area of application is not necessarily an indication of that migration, because in general the active ingredient is located on the surface of the granule and is rapidly released. Therefore, granules found off-site may only contain inert materials.

In general, the floor of the plantation is maintained free of all weeds (bare). Adequate control of the population, utilizing maximum shade, helps to minimize the growth of weeds. Weeds are controlled manually and with chemicals. Chemical control is used more frequently because it is much cheaper than manual labor. To reduce herbicide applications, the organic residues are deposited as ground cover or mulch. Cycles of herbicide application depend on quantity and type of weed. Applications are normally made every 4 to 6 weeks. The most common herbicides are paraquat, diquat, ametryn, glyphosphate, and ammonium glyfosinate. An average of 0.5 to 1 liter per hectare per cycle is applied in liquid form sprayed from tanks worn on workers´ backs (Sanchez, 1996).

Chemical residuals are transported outside the system by wind and water. It is very difficult to quantify the volume and concentration of these residuals. The best available method to determine the extent of the pollution is to sample and test surface and subsurface waters. However, due to the extensive drainage system required for banana production and the dilution from high rainfall amounts, variations in concentration level are often large and can vary from day to day.

Testing programs to obtain reliable statistics are both complex and expensive. Currently, there are no long-term databases that can be used to clearly quantify the extent of the nonpoint residuals problem and develop appropriate policies for dealing with it in Costa Rica. A solution to this problem needs to be a high governmental priority. Perhaps a tax that can be passed on to the international consumer could fund such a program as they, too, will benefit from more environmentally sound production systems.

2.6.2 Point Source Degradable Wastes

The raceme stem is the central shaft of the banana plant to which the banana fingers are attached. The stem is discarded once the fruit is harvested and becomes a significant source (volume) of residual organic solids. Disposal methods for the stem depend on where the waste is generated. Some plantations detach the fruit from the stem in the field, but the majority remove it at packing plant.

Before 1993 most plantations removed the stems at the packing plant and disposal was limited to transporting them to dumps. Traditional these dumps were open-air sites that were often located along riverbanks. The stems deteriorate rapidly, and the residues were eventually carried away by floodwaters. Once in the river, this residue hampered boat transportation. Also, the deteriorating stems often had a pronounced impact on the water's oxygen content, limiting or killing aquatic life and adversely affecting the overall aesthetic conditions for those who lived on the banks of the river.

Most commercial planters have realized that these wastes are valuable organic fertilizers. At the present time, stem disposal consists of spreading the discarded stems and leaves across the plantation floor, either whole or chopped. Chopped stems decompose fairly rapidly, adding water and nutrients to the soil and providing weed control within the plantation's boundaries. Value-added alternatives are extracting the fiber to manufacture paper and removing the sap to produce organic fertilizers. EARTH College has been successful in developing an economically viable process for producing paper from the stems.

From 16 to 25 percent of the bananas produced do not meet export standards because of handling bruises, scars, stains, crown infections, mutilated fingers (a cluster of bananas is referred as a hand and the single banana is called a finger), and unacceptable dimensions. Of these, small percentages are exported as second-class fruit at a considerable price reduction. Before 1993, most plantations deposited the remaining bananas in the same open-air dumps as the stems. Since then, the industry has explored alternative uses for these damaged bananas. Several industries have started processing these bananas into puree, juice, chips, and baby food. Some farmers use these bananas as cattle feed with favorable results. The extraction of starch from bananas is a feasible alternative that is being researched. All of these alternatives create the opportunity for more economic growth in Costa Rica and are more environmentally responsible than dumping.

2.6.3 Point Source Liquid Waste

A large quantity of high-quality water is required during the banana packing operation. Water is used to cushion the fruit during handling and transportation from one section of the process to the next, as well as to clean the fruit and processing facilities. EARTH College's packing plant uses approximately 12 liters of water per second to process 4000 boxes of bananas during a 10-hour day (108 liters per box of bananas shipped). When extrapolated to the yearly production of Costa Rica, the total water required for banana production is 12.1 million cubic meters of water per year. Even though the production regions have no shortage of water, this is a great deal of contaminated water to return untreated to the environment.

Bananas have a flower attached at the tip of the fruit at the time of harvest. When the flower is removed at the packing plant, the fruit oozes a white milky latex. This latex is also produced from the wound created by removing the fruit from the fruit stem and sculpturing the crown (point that attaches a cluster of bananas). If not handled properly, the latex will stain the fruit and make it unacceptable for the export market. Consequently, it is necessary to wash the fruit as soon as possible after removing the flower and forming the crown. The fruit will continue to secrete latex unless a coagulant—alum (aluminum sulfate)—is added to the wound. Because the wound is also susceptible to fungus, it is necessary to treat the crown of the banana with Mertak, a fungicide. The flowers, the crown chips, the latex, the Alum and Mertak pose a risk of contamination for the surface water downstream of the packing plants.

To address this problem, most packing plants have added water filter system to remove the solids from the water. Tests on the water following filtration have found that aluminum has been kept within acceptable limits, and biological oxygen demand (BOD) was approximately 26 ppm. However, test performed by the National University of Costa Rica have shown traces of biocides in the residue waters. In response to these findings, some plants have begun programs to contain, collect, and treat the chemical residues using clay to immobilize and, in time, biodegrade the active ingredients.

The next step in the process will be to reduce the amount of water used by reengineering the packing process, to purify the residual water and to recycle it. Finally, the hope is to eliminate processing water as a point source of pollution. This may be accomplished using engineered wetlands as a secondary treatment, but further research is needed.

2.6.4 Point Source Nondegradable Waste

Plastic bags have been used in banana production for 30 years. Workers put bags over the banana raceme when the fingers start pointing upward. The bags perform three basic functions: (1) they are a physical and chemical barrier to insects; (2) they serve as a barrier to contaminants (i.e., fungicides for black *Sigatoka* control); and (3) the plastic creates a micro-environment that stimulates fruit development. Bananas produced without plastic bags have a 10 percent higher rejection rate from the transnational companies than do those produced in a bag. This 10 percent is worth $60 million per year to Costa Rican producers, so the bags will continue to be used.

Plastic is traditionally sold in precut bags, a wasteful practice because plants are not entirely uniform in size. An alternative is to purchase plastic by the roll so it can be cut to the precise size needed for each fruit raceme. At EARTH College this practice has resulted in a 25 percent reduction in the amount of plastic used and yearly savings in material costs of US$15,000 ($49 per hectare). There is no significant difference in the amount of labor required.

Before 1993, the traditional disposal method was to simply rip the bags off and throw them on the plantation floor or dump them into the open-air disposal areas. If all of the plastic bags used in banana production in Costa Rica in 1991 were joined together, they could form a greenhouse large enough to cover the country's entire banana production region (EARTH, 1991 - Statement made by Diego Escorriola). Thus, suitable disposal is not a small problem.

The most promising environmental breakthrough for the disposal of plastic bags is recycling by melting and reformulating. A plastic bag recycling plant is now operating in Costa Rica that processes the bags generated by 70% of the hectares planted. A significant amount of the remaining 30% is collected, part is exported and part is stored for future treatment (Recyplast, 1997).

Another significant nonbiodegradable residual of banana production is plastic twine. The twine is used to anchor the bananas, so that the weight of the fruit and the wind will not collapse the plant. Traditional harvesting methods include discarding the twine directly onto the plantation floor. The twine is not biodegradable and accumulates over time. Eventually, the soil becomes so contaminated that development of an adequate plant root system is impaired and mechanical tillage becomes all but impossible.

Research into alternatives has included bamboo supports and biodegradable twine. However, neither alternative has proved to be feasible for large-scale production. The plastic twine is 40 percent cheaper, less time-consuming to attach, and easier to use; thus, it will continue to be used. In some countries, the twine is reused after several strands of discarded twine are braided together. This is not common in Costa Rica, but may offer the chance for cottage industries surrounding the plantations where residents could harvest the twine from the plantation, braid it, and sell it back to the plantation. Outreach educational programs are needed to make the locals aware of the opportunity and teach the skills necessary for them to take advantage of it.

Since 1994, a plant that recycles plastic operates in Limón, Costa Rica that treats approximately 20% of the waste material generated. Most of the remaining twine residue is collected and stored for future solutions. Among the most promising solutions is the use of these residuals as fuel for cement production. The Industria Nacional de Cemento (INCSA), in Cartago, Costa Rica, has tested plastic incineration with respect to the air pollution control equipment installed at this factory with promising results. INCSA offers to pay seven cents of a US dollar per kilogram of twine cut into 3-centimeter strips and relatively free of contaminants. Several companies are looking into the logistics necessary and the economical feasibility of this alternative. These are promising trends for Costa Rica's environment and should also produce additional revenues.

2.6.5 Hazardous Waste - Agrochemical Containers

It is difficult to project the magnitude of the container problem on a national scale, because of the large variation in the size and type of containers used. An estimate by McNeel International Corp. (Personal letter March 10, 1997) reveals the following annual generation of residual packaging for 1996 in the banana industry: one hundred and four tons of recyclable HDPE agrochemical packaging, five-hundred and ten tons of steel packaging and one-hundred and sixty eight tons of paper packaging.

The primary environmental risks associated with agrochemical containers are handling them (spilling) and storing them (leakage). The solution is risk prevention through appropriate handling procedures, containment structures, and spill control. The chemical manufactures have ample recommendations and the government of Costa Rica has regulations for the design and operation of these facilities. The problem is in the implementation by the producers. Since 1993, most of the large plantations, especially those owned by the transnational companies have started building adequate facilities and have appropriate procedures for handling agrochemicals in their installations. However, due to the high cost of these improvements and the low market prices for bananas, a considerable number of plantations still have inadequate facilities.

The airports from where the cropdusters operate constitute a major area of environmental risk. A recent visit with EARTH students (July 1997) to the Batan, Limón airport revealed the efforts made by Dole and del Monte to ensure safe storage, appropriate and safe handling of the chemicals by the operators, containment and control of residuals and spills, recycling of residual liquids, and handling of used containers. During this stay, it was possible to witness that the chemical companies are picking up the used containers and removing them from the working site for treatment or storage at their installations. Nonetheless, it also revealed the lack of prevention mechanism by other cropdusting operations. In this occasion a plane (not part of Dole or del Monte's operations) had a mechanical failure and the load was spilled over the runway. The chemical was rinsed off the runway into a drainage ditch with no efforts to contain the spill or treat it. The obvious presence of agrochemicals in the drainage ditches around this airport showed that this incident was not an exception caused by an unfortunate accident. It also evidenced the absence of government inspectors and control personnel.

After risk prevention, the next best procedure is recycle the used containers. The best procedure for recycling is to send the entire container back to the company to be filled and reused, much like Coca-Cola bottles. This system is fairly widespread in the United States and it is currently being introduced in Costa Rica for fungicide and nematicide containers. At the present time most banana producers have included in their agrochemical purchasing agreements a clause that obligates the distributor for the collection and treatment of the empty containers.

The government of Costa Rica currently will not issue permits to for the incineration of hazardous materials, including plastic containers. Therefore, most empty non-recyclable pesticide containers are kept at storage facilities. They represent a real and present danger to Costa Rica's environment and citizens. Some companies are reducing this risk by triple rinsing, compacting and storing for future treatment.

Notwithstanding extensive education campaigns, often people, both rural and urban, use the plastic and metal containers to hold water and grain that are later used for human consumption. Again, there is a need for government or university outreach programs to educate people about the risks and help them find safer alternatives. Furthermore, it is necessary to enforce the laws and force all the chemical companies into assuming direct responsibility for disposing of their used containers.

2.7 The Challenge

Costa Rica has passed a number of laws in an attempt to protect its citizens and environment from human-introduced environmental hazards. Enforcement of these laws in Costa Rica, as in most of the world, remains a major problem. Only recently have some banana producers recognized the environmental impacts of these combined problems. Their interest is primarily based on fears of how international consumers and markets will react to documented or inferred cases of environmental and/or human poisonings (EARTH, 1991).

In order to implement rapid change, it may be most important to determine what it will take to influence international consumer preferences to buy a banana that may not have a perfect skin color or size, but can be produced without further damaging Costa Rica's environment. Producers will follow consumer demands faster than laws can be passed or environmentalists and politicians can articulate their fears and concerns! Until this happens, though, we must continue to seek more and better practices for producing bananas to meet the worlds needs.

Conclusion

This chapter systematically depicts the environmental impacts associated with banana production and some of the historical, political, and economic reasons why these conditions exist. The challenge for the fifth paradigm (ecodevelopment) in the evolution of banana production is to reconcile production methods and economic needs with the conservation of Costa Rica's environment. This will require long-term commitment from Costa Rican producers, transnational producers, the government of Costa Rica, the research community, and the consumers of Costa Rican bananas.

Promising signs of improvement and changes in the attitudes and actions of some producers are apparent in the emplacement of plastic recycling plants, introduction of recyclable fungicide and nematicide containers, mulching of organic wastes, and turning non-biodegradable wastes into new commercial products. These changes may stem from fear of a possible consumer boycott, the recognition that traditional technologies are self-destructive, or the development of an environmental ethical code of conduct. But regardless of the reason, since 1991 the environment is a common theme of discussion among banana producers. At the same time, it is also evident that producers and the research community do not yet fully comprehend the complex interactions between humans and their environment, and that there are many problems that have no solutions at the present time.

History shows that changes in paradigms (e.g., from frontier economics to ecodevelopment) are slow to occur and that the period of change is filled with conflict between immediate needs for economic gratification and the perceived needs of the next generation. The questions that cannot be answered yet are:

How fast will the environment deteriorate?

What will be the impact on Costa Rica's economy and citizens?

Will producers be willing to change even if it means lower profit margins?

Will world consumers be willing to share in the cost of growing a different type of banana?

If the stakeholders who depend on banana production maintain their traditional ways and rely only on new technology to overcome production problems, the future is not bright. Such practices, when combined with the economic theory that allows for the substitution of new resources to meet consumer needs, may also allow a transnational company to simply move to another country and leave Costa Rica holding the proverbial (plastic) bag!

Chapter 3

METHODS

3.1 Introduction

The first chapter of this dissertation defined a vision, a blue print to guide those responsible for agro-production systems to see the world as a complex system that requires responsible stewardship. H. T. Odum defined stewardship as a management strategy of the planet that pursues a cooperative role with the planetary support systems (in Mitsch and Jorgensen, 1989). Accordingly, Chapter I advances the philosophy of sustainability, and dissects it into three basic components -- environmental, social and economic sustainability. It also promotes the analysis of systems through the use of systems theory, defining it as the study of complexity. Chapter I introduces a world-class banana production system as a specific case to test the validity and appropriateness of the systems approach.

The second chapter recognizes the present state of affairs of world-class banana production. It uses pertinent literature to identify the problem, its size, its causes, and possible solutions. It introduces a model advanced by Hernández and Witter (1996), that outlines the production system. The Hernández and Witter model (H & W model – Figures 13 and 14) is a schematic drawing that portrays, in a palpable manner, the limits of the system under consideration and the different components of the system. It defines inputs and outputs, and it evinces the interactions among components of the system. It is an attempt to bring order to the apparent chaos of complexity, interdependence, and interactions. However, it lacks one fundamental element. It does not render precise intensities for each of the interactions. The definition of intensities is the next task of this dissertation.

As defined in Chapter I of this dissertation, an agricultural production system is an open system. Open systems are complex and interdependent on other adjacent systems. The complexity of open systems require a systems approach, which was defined as a

> *"way of thinking about the set of interconnected parts that makes up the whole in sucha away as to bring out the properties of the whole rather than those of the parts (Peet, 1992, p. 21)."*

Thus, the problems that arise from agricultural production cannot be studied in isolation.

> *"They cannot be factored out of the whole, each explained on its own and the set of explanations thrown together to explain the whole (Saaty and Kearns, 1991. p. 3)."*

Furthermore, open systems are not static because the environment that surrounds them is continually in flux (Odum – personal communication, 1995).

Under these conditions, the definition of intensities is a difficult task because it involves measuring interactions between the production system, and the environment, the society and the economy. Each of these components has different instruments and scales of measurement. Furthermore, it is important to acknowledge that there is meaningful information that is not derived from the traditional scientific method, and that can not be measure with physical instruments. This is especially true when dealing with human perceptions, values and feelings. If the objective is to influence decision makers to act according to the blueprint which was defined in Chapter I, then these perceived values are an important catalyst of choice. As stated by Saaty and Kearns (1991, p. 7)

> *"addressing these problems requires an approach which enables us to use a variety of relevant information including both 'hard' data, such as quantifiable information, and 'soft' data derived from intuition, experience, values, judgments and imaginative guesswork".*

This dissertation proposes a systematic method to assign intensities and derive performance indicators based on systems theory. The method is appropriate for studying problems and choosing the best solution from an array of alternatives. In essence, this is a decision-making method that has six steps leading to one objective. The steps are the following:

- define a typical conventional production method,
- identify the problems and impacts of this method,
- identify feasible solutions,
- establish criteria and standards,
- assign relative importance to the criteria, and
- rate each alternative solution to derive performance indicators according to the degree of fitness with the chosen criteria and standards.

The objective is to choose the alternative solution with the highest performance indicators. Because of complexity, the method considers

> *"multiple criteria or objectives, many of which are intangible, or subject to uncertainty and risk, and vary in purpose and function (Expert Choice, Inc. 1995, p. 181)."*

This chapter describes the method that was used to dissect the H & W model, define production methods, identify cause and effect relationships, define and prioritize criteria, and assign value to the performance of production techniques in minimizing negative impacts and maximizing benefits on the environment (Environmental Performance Indicator - ENPI), the society (Social Performance Indicator - SOPI) and the economy (ECPI). The weighted combination of the ENPI, SOPI and the ECPI results in the Sustainability Performance Indicator (SPI).

The method used a multicriteria decision making tool based on the Analytic Hierarchy Process (AHP) developed by Dr. Thomas L. Saaty at the Wharton School of the University of Pennsylvania. A decision support software package designed by Dr. Ernest H. Forman - ECPro for Windows by Expert Choice, Inc.- was identified that organized this process, prepared the questionnaires, did the relevant calculations, checked the consistency of the system, and rendered the reports.

A synopsis description of the proposed method follows: the foundation of the method was the H & W model (Figures 13 and 14 in Appendix A). The most significant production activities (predictor or independent variables) were identified, listed and defined from the literature, field visits, and the authors practical experience. The list of activities was consulted with a Panel of Experts (See Appendix B, Table 36 - Independent Variables) and modified accordingly. Cause and effect diagrams were assembled (See Appendix A, Figures 15 through 36) and the H & W model was expanded (See Appendix A, Figures 37 through 39). These diagrams were consulted and modified according to the individualized opinion of a Panel of Experts (PE). The criterion (or dependent) variables were identified from the cause and effect diagrams, and a hierarchy structure (See Chapter 4, Figures 7 through 10), with levels of relative importance among the criteria, was assembled.

The next step was to assign relative weighted importance to each criteria at the different levels of the hierarchy structure. When available, 'hard' data (i.e. cost data) was introduced to define the comparative weights among criteria. In the absence of 'hard' data, comparative value data was gathered using a verbal argumentative approach through one-on-one personal interview of a Panel of Experts (PE) in banana production. Table 14 in describes the members of the PE and their contribution to this dissertation.

The Delphi method[14] was used for interviewing. Experts assessed relative weights using the questionnaire prepared using the ECPro software and the

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[14] The Delphi method is a well known process that gathers information and seek consensus from a panel of experts while keeping their names anonymous and confidential. Each member of the panel responds to a previously prepared questionnaire and the answers are reviewed by the rest of the panel allowing for adjustment and consensus (Saaty, 1996).

intensity scales defined by the AHP method (Saaty and Vargas, 1994, p. 6; Saaty and Kearns, 1991, p. 27).

The predictor or independent variables were divided into two categories - Conventional Production Practices (CPP) and Best Available Practices (BAP). Expert opinion evidenced the existence of more than one alternative Suggested Production Practice (SPP) for some tasks. However, the SPP are not necessarily the BAP. It is necessary to rate these practices and judge if they are trully better and if they are available at the present time. For this reason, several SPP treatments were analyzed and differentiated by a numerical subscript. The suggested alternative methods of production, or the SPP, were rated for each of the bottom-line criteria of the hierarchy structure using the AHP value scales (See Tables 7 through 10 in Section 3.4.2). If 'hard' data was available, this data was transformed and adjusted to fit into the AHP value scale.

Table 5 - Panel of Experts

Expert N#	Description	Contribution
1	Independent producer	Evaluator
2	Educator and researcher	Environmental Advisor
3	Educator	Evaluator
4	Transnational employee	Evaluator
5	Independent financial consultant	Evaluator
6	Transnational employee	Social Advisor
7	Environmental labeling group	Evaluators
8	Independent production consultant	Evaluator
9	Researcher	Evaluator
10	Independent producer of organic bananas with direct marketing	Environmental Advisor

11	Farm manager for an independent producer	Evaluator
12	Researcher	Evaluator
13	Private consultant – Environmentalist	Evaluator
14	Educator and researcher in anthropology	Social Advisor
15	Educator, researcher and independent producer	Evaluator
16	Group of transnational employees	Production Advisors

In order to compare the CPP and SPP to a standard for sustainable practices, the researcher assumed that a sustainable system tolerates a moderate amount of negative impact and that a Sustainable Production Practice (SPP) corresponds to a moderate (0.60) SPI.

The data was introduced into the ECPro software. This program organized the data in square reciprocal matrixes (See Figure 5 in Section 3.4.1 - Pairwise Comparison Matrix). Mathematical calculations were processed by the ECPro software using eigenvectors and eigenvalues as described by Saaty and Kearns (1991, pp. 22-38). Consistency was checked by calculating a consistency ratio (CR) (Saaty and Kearns, 1991, p. 33). The Delphi Method permits the researcher to discuss results with the experts with the purpose of reviewing assessments to improve consistency and seek consensus.

The end product was an aggregated Sustainability Performance Indicator (SPI) which is composed of an aggregated Environmental Performance Indicator (ENPI), Social Performance Indicator (SOPI) and Economic Performance Indicator (ECPI) for the total analysis and for each production task (Predictor Variable). The derived intensities introduced into the AHP, a product of the opinions stated by the PE, correspond to the intensities for each of the interactions described in the modified H & W model.

The scale used to derive the indices was a ratio scale with a range from zero to one. The data was assumed to be normally distributed and a parametric statistical method was used to test the significance of the results. The author recognizes that this was a gross assumption. However, Earl Babbie (1983, pp. 427-428) has the following comments on tests of significance:

> *"Test of statistical significance, strictly speaking, make assumptions about data and methods that are almost never satisfied completely by real social research. Despite this, the tests can serve a very useful function in the analysis and interpretation of data...I encourage you to use any statistical technique - any measure of association or any test of significance - on any set of data if it will help you understand your data...You should be wary of interpreting the 'significance' of the test results too precisely, however...Anything goes, if it leads ultimately to the understanding of data and the social world under study."*

The results were arranged in a two-way classification by treatments and by replication. The three treatments considered were CPP, SPP and SPP (See Table 6 - Aggregated Two-way). The ten replications correspond to the opinion of the ten experts. The hypothesis stated that the results were samples of the same population and that variance was a result of random error. An analysis of variance of a two-way classification system was used to test the hypothesis with an F-test. In case the hypothesis was rejected, an orthogonal variance analysis was conducted to identify which sample had variations beyond expected random error (Snedecor and Cochran, 1973, p.299-311).

Table 6 - Aggregated Two-way Classification

Expert Opinions = Replications (nk)	Treatments (k)		
Expert Number	CPP	SPP	SPP
1	SPI_{1CPP}	SPI_{1SPP}	$SPI_{SPP} = 0.60$
2	SPI_{2CPP}	SPI_{2SPP}	$SPI_{SPP} = 0.60$
3	SPI_{3CPP}	SPI_{3SPP}	$SPI_{3PP} = 0.60$
...	...	...	...
n=10	SPI_{10CPP}	SPI_{10SPP}	$SPI_{SPP} = 0.60$

This chapter is divided into seven sections, the first being this introduction. The second section re-states the problem, identifies the critical questions raised by the problem statement, states the assumptions made, and sets the tasks for answering the questions. The following section describes the panel of experts that took part in the study. The fourth section describes the instrument and measurements that were used in the study and the fifth section enumerates each of the steps that were taken. The sixth section is dedicated to outlining the statistical techniques that were used to analyze the data and test the hypothesis. This chapter concludes by stating the limitations of the study. The results of the application of the method are presented in the next chapter.

3.2 Problem Setting

3.2.1 Restatement of the Problem

The facts presented in Chapter 1 and 2 document the following statements:

- All agricultural production practices introduce a disturbance in the ecosystem and have a resulting impact on the environment, society, and the economy. A production practice performs in a sustainable manner when the negative impact on society and the environment are minimized, and the benefits to society and the economy are maximized.

- The environment has the resiliency to assimilate a moderate amount of disturbance. Conventional production practices (CPP) for growing bananas introduce a massive disturbance in the ecosystem and their impact may be beyond the limits of environment to absorb the insult. Therefore, banana CPP may not be performing in environmentally sustainable manner.
- Banana CPP brings many benefits to the workers, neighboring communities and the nation, but they also may be directly or indirectly responsible for part of the serious social problems evidenced in the banana production region. Furthermore, banana exports require a large national resource investment that generates a substantial economic benefit to a few transnational firms, national firms, and individuals. Conventional development paradigms rely on the trickle down effect for benefits to reach all the stakeholders. The present structure of ownership and marketing of bananas may provoke a deficient distribution of benefits. Therefore, banana CPP may not be performing in a socially sustainable way.
- The present banana market conditions may be generating insufficient economic benefits to Costa Rica that may not compensate for the negative impact on the environment and society. Therefore, CPP may not be performing in an economically sustainable pattern.
- Consequently, the banana CPP used in Costa Rica may not have an acceptable sustainable performance level and it may be necessary to introduce best available practices (BAP) to improve the net benefit.
- BAP may also have negative impact on the environment, the society and the economy. Therefore, BAP may not achieve an acceptable level of sustainable performance.
- If both CPP and BAP are not performing to a desired level of sustainability, then it may be advisable to abandon banana production. However, the negative impact on the environment, society and the economy of Costa Rica of abandoning banana production may be catastrophic. Alternatives to banana production may perform in a less sustainable manner. Therefore, it is critical to collect information, appraise it and organize it, using a systematic method, to identify areas that require further research and development, and to aid decision makers in taking sustainable actions.

3.2.2 Research Questions

An analysis of the problem statement presented in the previous section, indicates that, the proposed method must answer the following six critical questions:

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1. What are the important criteria that must be met in order to perform in a sustainable manner?

2. What are the CPP?

3. According to the PE and in reference to a set of criteria and standards, are CPP performing in an environmentally, socially and economically sustainable manner?

4. According to the PE, are there SPPs other than the CPP or are the CPP the best available practices known?

5. If the CPP are replaced by SPP, will they have a better environmental, social and/or economically sustainable performance?

6. If the answer to question 2 and 4 are negative, what areas should be further researched and developed to improve sustainable performance?

3.2.3 Assumptions

In order to answer the questions stated before, it was necessary to make the following premises:

1. A great deal of the information required to make a decision is not "hard" data, but based on opinion and perceptions. Expert opinion is a valid method of collecting data as long as the instrument used is valid and systematically applied. The AHP is a well documented and validated instrument for collecting data based on systems theory (Veroutis and Aelion, 1996; Saaty, 1996; Saaty and Vargas, 1994; Saaty and Kearns, 1991; and Saaty and Vargas ,1991).

2. Consistency, in the opinion of experts, is an important element, but not irreconcilable in accomplishing the objectives of this research.

   "Perfect consistency in measurement even with the finest instruments is difficult to attain in practice...(Saaty and Kearns, 1991, p. 33)." "A central point in our approach is that people are often inconsistent, but priorities must be assigned and things done despite inconsistency (Saaty, 1996, p. 9)." Therefore, "...what we need is a way of evaluating how bad it (consistency) is for a particular problem (Saaty and Kearns, 1991, p. 33)",

   and decide whether the resulting level of inconsistency is tolerable. Therefore, there is a tolerable level of inconsistency acceptable to reach a conclusion. According to Saaty (1996) a 10% consistency is acceptable.

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Values between 10 and 20% should be verified and values over 20% must be rejected.

3. The world-class quality standards cannot be changed in the short term. Therefore, it is sensible for this research to hold this variable constant.

4. The oversupply of bananas in the market makes the banana market a buyers' market. Therefore, the market price of bananas is beyond the producer's control. On the basis of marketing experiences and research, producers must assume that consumers are not willing to pay more for world-class bananas that are produced in a sustainable manner. Therefore, the producers that adopt BAP must minimize cost and assume any additional cost that may arise.

5. Established on experience, producers must assume that a large sector of consumers are willing to choose world-class bananas that are produced in a sustainable manner over ones that are not if there is no difference in price. Therefore, there exists a market share advantage for producers that make the necessary changes to improve their production system.

6. There are trustworthy labeling mechanisms that allow the producer to sustain claims about the method of production used. Therefore, the consumers can trust the labels to make their choice.

7. Any and all systems of production cause a disturbance in the environment and society. Production practices that cause no negative impact are impossible. There are levels of sustainable performance which range from a very low level to a very high level of sustainable performance. Therefore, it is reasonable to assume that sustainable production practices consist of a balance between positive and negative impact to the environment, society and the economy, and that sustainable systems tolerate a moderate amount of negative impacts.

8. Banana plantations in Costa Rica, by law and by market attrition, are located in areas that posses the optimal ecological conditions for their growth. Therefore, climatic and edaphic variables are assumed to be constant.

3.2.4 Tasks

The abridged description of the tasks performed to seek answers to the questions presented in section 3.2.2 are as follows:

1. Select a panel of experts (PE) and interview individually each of the experts. Consider the information from each individual expert as a repetition of the experiment.

2. Divide the H & W model into three separate models - environmental, social and economic models.

3. Transform the information presented in each of these three models into environmental, social and economic cause and effect diagrams, and validate this information with the PE.

   Convert the information in cause and effect diagrams to three separate (environmental, social and economical) hierarchial structures of goals, criteria, sub-criteria, and standards. Work with each hierarchy structures independently to derive an ENPI, SOPI and ECPI. Load this information into the ECPro software to create the horizontal elements (criterion variables) of the rating matrix.

5. Determine, with the help of the PE, the relative weight of the ENPI, SOPI and ECPI to determine the SPI.

6. Define, with the help of the experts, the CPP and SPP for each production task. Load this information in the ECPro software to create the vertical elements (predictor variables) of the rating matrix.

7. Determine, through expert opinion and hard data, the relative weights of the environmental and social hierarchy structure and load the information into the ECPro software. Use the pairwise comparison module or the data module to register expert opinion into the software depending on which system is more comfortable for the expert. The software program transfers and assigns these values to each of the horizontal elements of the rating matrix. Since the relative weights for the environmental and social impact vary depending on the impact of each individual production task, create a separate program for each task.

8. Determine the relative weights of the economic hierarchy structure by identifying an economically sustainable farm and unloading hard data into the ECPro software. Identify this farm with the help of the PE.

9. Verify consistency and validate results with the each of the members of the PE.

10. Assess the CPP and SPP through individual expert's opinion and load separately the results into the rating matrix of the ECPro software.

11. Run the ECPro software and determine the indices for each of the experts opinion for each task separately and calculate individual ENPI and SOPI. Combine the individual ENPIs and SOPIs into single values by assigning

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relative weights to each of the tasks and calculating the average weighted value.

12. Classify the results in a two way matrix - - treatment versus repetition . Consider each expert opinion as a repetition of the experiment. Place the treatments (CPP, SPP, and SPP) in the columns and the repetitions in the rows, and test the hypothesis statistically using SPSS software.

13. Set the SPP rating at a value of 0.60.

14. Test the hypothesis using ANOVA. If rejected, test the hypothesis with an orthogonal comparison.

15. Recommend changes in production practices and areas for further research and development.

3.3 Participants

The validity of data derived from expert opinion depends on the use of diversity of disciplines and plurality of convictions. Nonetheless, the arbiters must have similar objectives and have a positive constructive attitude towards improving the sustainable performance of the banana production process. Furthermore, judges must be well-informed generalists who have sufficient expertise to understand, analyze, and assess the impact of the different tasks of the production process on the environment, the society, and the economy. As discussed in section 3.2.3, the assessments by the experts must meet a minimal acceptable degree of consistency. For these reasons, the selection of the PE was purposive and non-random.

Due to the complexity of the problem, it was necessary to include specialists in the PE who did not participate in the predictor variable assessment process. This specialized group of experts contributed to their areas of expertise, such as the definition of social and economic criteria and their weighting. Only the experts that were judged competent to voice an opinion on the three areas of assessment were asked to rate the independent variables. From the statistical perspective, the heterogeneity of the PE improves the non-dependency of the treatments.

The experts were chosen based on their recognition as academic researchers and educators, authors of related books and articles, prominent independent producers, transnational staff working in the conservation of the environmental, production practice innovator, members of trade organizations, regulatory government agents, and members of certification bodies. The names were selected from a short list that was drawn with the help of EARTH's faculty and staff.

The experts chosen were offered confidentiality to assure them that their opinions would be kept as personal and not as official positions of their employers. A letter of informed consent was signed by the each of the experts and the researcher. A copy of this letter remained with the expert and the originals were deposited in a sealed envelope with the comptroller of EARTH College for safekeeping. A copy of a sample letter was included in Appendix B and is labeled Figure 34 – Agreement to Participate.

Since this is, in essence, a qualitative dissertation and uses intensive interviews, the number of experts that form the panel relies more on what is deemed reasonable and convenient to develop a convincing argument, and less on statistical testing arguments (Rudestam and Newton, 1992). The minimum numbe

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number of panel members was judged to be ten. However, fourteen experts were chosen and were asked to contribute in developing the criterion and predictor variables. Ten experts were asked to participate in the second phase – Assignment of Values and Ratings.

Confidence in the results depends on extracting results in line with the majority preference. Saaty (1996, p. 66) recommends reaching consensus in judgment by group discussion. Focused interviews and group sessions were not appropriate since panel members were assured confidentiality and their opinions had to be kept anonymous. The next best method was chosen. Each expert was interviewed separately using the Delphi Method (Saaty and Kearns, 1991, pp. 115-118, Saaty, 1996, pp. 66-70). To improve confidence, validity, and consistency, the resulting data was discussed with each of the panel members giving them the opportunity to comment and review their contribution.

Although the ECPro software has the capability of calculating and loading geometric averages for multiple opinions, the data obtained from each panel member was loaded individually and the program was run obtaining ten repetitions of the experiment for two treatments – CPP and SPP.

To maintain confidentiality, the names of the panel members were not revealed to the other members of the panel or made public in this document. Additionally, identification numbers were assigned to each of the panel members and data was stored under their ID number.

3.4 Instrumentation and Measures

3.4.1 Analytic Hierarchy Process and ECPro

As stated previously, the necessary task to complete the H & W model was to calculate the intensity of the different interactions. Once the intensities were determined, then it was possible to calculate the sustainable performance level of each production process on the environment, the society and the economy. The instrument used to accomplish this task was the AHP, and ECPro was the software used to perform the mathematical calculations and organize the results.

The theory behind the AHP was developed in 1971 as a contingency planning tool for the Department of Defense. Since then, it has been used extensively for many applications such as architectural design, designing mousetraps, selection of bridges, determining market attractiveness of developing countries, development of new product pricing strategy, etc. The researcher became aware of this process by Veroutis and Aelion's (1996) use of this tool for total environmental quality management. The researcher was able to contact Veroutis by phone, and he recommended the software.

The researcher examined five books (Saaty, 1996; Saaty and Vargas, 1994; Saaty and Vargas, 1991; Saaty and Kearns, 1991; and Expert Choice, 1995) specifically related to AHP, and there was no reference to the use of this process for assessing sustainability or calibrating a agro-production model. The innovative use of this method advances a validated procedure that can be easily replicated for modeling other agricultural production processes and testing their sustainable performance.

The AHP is based on the theory of operation of the human mind. The thought process of an individual involves the identification of complex problems and their decomposition. Then, relationships are identified among decomposed elements and these relationships are prioritized into a hierarchy structure. Finally, all the information is synthesized and a decision is made (Saaty and Kearns, 1991, p.19-22). AHP uses matrix analysis grounded on sound mathematical theory. Expert Choice, Inc. has developed a software called ECPro that facilitates the use of AHP. ECPro guides decision making through seven basic steps (Expert Choice, 1996, p. 184):

1. Defining problem and research
2. Identifying feasible alternative solutions
3. Structuring a model
4. Making judgments
5. Synthesizing
6. Examining and verifying the decision
7. Documenting the decision

The purpose of each step is to organize knowledge and data in a logical process. The first step requires the execution of the following tasks:

1. Re-state the problem and the questions that need to be answered.
2. Confirm the objective and the criteria for fulfilling it.
3. Determine the standards for rating performance of the alternatives.

These steps are basically accomplished in Chapter I.

The next step is to identify as many feasible alternative solutions as possible through

> *"brainstorming, wide discussion, research into what is available, and solicitation of ideas and views from others (Expert Choice, 1995, p. 186)."*

Chapter 2 of this dissertation searches the literature for alternatives, and advance some recommendations by Hernández and Witter (1996). Other alternatives, ideas and views were solicited by interviewing the panel of experts.

The third step organizes all the available information into a logical hierarchy by identifying the components of the problem, grouping them in clusters according to the relationships shown in the model, and prioritizing these clusters. The software manual identifies two approaches for this structuring process -- top-down and bottom-up. The top-down approach was used for this research because the information for establishing the hierarchy structure was provided through the H & W model and the cause and effect diagrams.

The top-down approach required the definition of an objective (sustainable performance of production processes) and placed the objective at the top of the hierarchy. The next layers in the structure were occupied by the criteria and sub-criteria necessary to meet the objective. The criterion variables were divided into three categories: environmental, social and economic. Each of these categories was further subdivided into specific indicators that were linked to the causes shown in the Cause and Effect Diagrams (Appendix A, Figures 15 through 36).

The following layers were occupied by the performance rating standards. The assignment of the levels of performance were done through expert opinion and the rating module of the ECPro software.

The production tasks (predictor variables) were chosen using Life Cycle Analysis criteria but the processes were truncated at the plantation limits. The resulting list of independent variables is presented in Appendix B, Table 36. Production processes begin with planting and population control and end with packing. Labor management processes were included separately and were listed in the same table beginning with labor contracts and ending with collective bargaining practices. Up-stream and down-stream processes were not included in the scope of this study.

The end product was a decision tree composed of parents, siblings, children, and grandchildren. Figures 7,8, 9, and 10 in found in Chapter four are the resulting hierarchy diagrams.

Expert Choice recommends a group process to do the structuring. Since confidentiality was a limiting factor, the group process was not appropriate. In this case, the Delphi method was used to enhance and validate the results with each member of the PE independently.

Once the hierarchy structure was completed, the fourth step was to compare elements of the structure at equal levels and to determine their importance or intensity with respect to their parent element. For this purpose, square and reciprocal comparative matrices were arranged by the software where the elements of the columns were identical to the elements of the rows. The comparison matrix is presented in Figure 5.

When 'hard' data was available, intensities were calculated directly using the data module of the ECPro software. In the absence of 'hard' data, comparative judgments were made by the experts using Table 7 - Scale of Relative Importance" which was validated in other AHP applications (Saaty, 1996, p. 54). However, the majority of the experts chose to enter their judgment directly using the data module of the ECPro software by assigning percentages to each criteria, then translating the results into pairwise comparisons and comparing validity and consistency. The software program has the build-in capacity to assist in performing this operation.

I = Row j = Column	C_1 $j = 1$	C_2 $j = 2$	C_3 $j = 3$	C_n $j = n$
C_1 $I = 1$	$a_{ij} = a_{11}$ $= WC_1 / WC_1$ $= 1$	$a_{ij} = a_{12}$ $= WC_1 / WC_2$	$a_{ij} = a_{13}$ $= WC_1 / WC_3$	$a_{ij} = a_{1n}$ $= WC_1 / WC_n$
C_2 $i = 2$	$a_{ij} = a_{21}$ $= WC_2 / WC_1$ $a_{21} = 1/ a_{12}$	$a_{ij} = a_{22}$ $= WC_2 / WC_2$ $= 1$	$a_{ij} = a_{23}$ $= WC_2 / WC_3$	$a_{ij} = a_{2n}$ $= WC_2 / WC_n$
C_3 $i = 3$	$a_{ij} = a_{31}$ $= WC_3 / WC_1$ $a_{31} = 1/ a_{13}$	$a_{ij} = a_{32}$ $= WC_3 / WC_2$ $a_{32} = 1/ a_{23}$	$a_{ij} = a_{33}$ $= WC_3 / WC_3$ $= 1$	$a_{ij} = a_{3n}$ $= WC_3 / WC_n$
C_n $i = n$	$a_{ij} = a_{n1}$ $= WC_2 / WC_1$ $a_{n1} = 1/ a_{1n}$	$a_{ij} = a_{n2}$ $= WC_n / WC_2$ $a_{n2} = 1/ a_{2n}$	$a_{ij} = a_{n3}$ $= WC_n / WC_3$ $a_{n3} = 1/ a_{3n}$	$a_{ij} = a_{nn}$ $= WC_n / WC_n$ $= 1$

Figure 5 - Pairwise Comparison Matrix

The researcher had originally planned to conduct the interviews and directly log the answers into a laptop computer. Using the ECPro built-in capability, questionnaires can be displayed in the computer screen to guide the experts in the evaluation process. However, due to the complexity and the extent of the resulting hierarchical structure, the time requirements to conduct the interviews, approximately eight hours, went beyond the limits of endurance of the experts. The majority of the experts chose to fill the questionnaires on their own and submit them to the interviewer later. Consistency was calculated and the expert was allowed to change his/her judgment to correct values in order to comply with allowable inconsistency ratios. By using the data module as a starting place and then translating to pairwise comparisons, consistency problems were almost entirely eliminated. A visual check for validity was made possible through a bar graph display available by using the ECPro software.

Saaty, in his justification of the judgment scale, quotes psychological experiments performed by Miller (1956) that show that

> *"individuals cannot simultaneously compare more than seven objects (plus or minus two) without being confused (Saaty and Vargas, 1991, p. 22)."*

Using the same criteria, comparative matrices were limited to less than five elements for pairwise comparisons. This was accomplished by clustering elements under similar criteria and subdividing into sub-criteria. An exception was registered in the economic matrix where it was necessary to include eight elements. However, in this case, the data was "hard data" which requires no expert judgment.

The fifth step was to load each of the CPP and SPP predictor variables into the Rating Spreadsheet in the ECPro software. Performance ratings were assigned by the experts using the ECPro rating module scales (decimal numbers with a range of zero to one). SPP with low ratings were pre-screened and discarded. The ECPro software was used to calculate the ENPI, SOPI, ECPI and the SPI. The results were synthesized and introduced into the SPSS software package.

3.4.2 Scales and Calculations

The use of the AHP and the ECPro software dictate the scales for the pairwise comparisons. The development, justification and testing of this scale is amply discussed by Saaty (1996, pp. 53-64) and by Saaty and Kearns (1991, pp. 44-45 and 26-28). The judgments are qualitative and have a corresponding scale value. The range of the scale is from 1 to 9. After the calculations are processed, the weighted intensity results are expressed in ratio values whose sum is equal to one. Table 7 - Scale of Relative Importance, describes the scale used.

Table 7 - Scale of Relative Importance (Saaty, 1996. P. 54)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favors one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between adjacent scale values	When compromise is needed
Reciprocals of above values	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *I*	A reasonable assumption
Rationales	Ratios arising from the scales	If consistency were to be forced by obtaining n numerical values to span the matrix

ECPro has the capacity to perform assessment with ratings (Expert Choice, 1995, pp. 125-149). This module of the program allows the user to integrate pairwise comparisons for assigning weights to criteria with the capacity to rate multiple alternatives. This process involves the rating of different alternatives against a standard. In this case the standard is the SPP that is assigned a rated value of 0.60, which corresponds to an acceptable sustainable performance. The scale values were translated into word descriptors in order to load the information into the ECPro software (See Figures 8 through 10). The indices of impact, calculated using ECPro, are expressed as decimal numbers ranging from zero to one, zero representing the least impact and one the maximum impact. The following tables describe the scales used for rating the different alternatives for environmental, social and economic impact.

Table 8 - Environmental Sustainable Performance Indicator Scale

Rating	Descriptor	Description
1.0	Ideal	Ideal environmental performance
0.8	Desirable	Desirable environmental performance
0.6	Acceptable	Acceptable environmental performance
0.4	Moderately Unacceptable	Moderately unacceptable environmental performance
0.2	Highly Unacceptable	Highly unacceptable environmental performance
0.0	Extremely Unacceptable	Extremely unacceptable environmental performance

Table 9 - Social Sustainable Performance Indicator Scale

Rating	Descriptor	Description
1.0	Ideal	Ideal social performance
0.8	Desirable	Desirable social performance
0.6	Acceptable	Acceptable social performance
0.4	Moderately Unacceptable	Moderately unacceptable social performance
0.2	Highly Unacceptable	Highly unacceptable social performance
0.0	Extremely Unacceptable	Extremely unacceptable social performance

Table 10 - Economic Sustainable Performance Indicator Scale

Rating	Descriptor	Description
1.0	Ideal	Costs of proposed production practice are considerably lower than those of conventional production practices
0.8	Desirable	Costs of proposed production practice are lower than those of conventional production practices
0.6	Acceptable	Costs of proposed production practice are equal to those of conventional production practices
0.4	Moderately Unacceptable	Costs of proposed production practice are slightly higher than those of conventional production practices
0.2	Highly Unacceptable	Costs of proposed production practice are higher than those of conventional production practices
0.0	Extremely Unacceptable	Costs of proposed production practice are considerably higher than those of conventional production practices

3.4.3 Consistency, Reliability and Validity

As shown in the previous section, clear process and structure of scoring were established to assure consistent results among the panel members. The hierarchical structure and the questionnaires were explained using graphical displays in the computer to assure understanding by the panel members. A few of the experts chose to enter the answers to the questionnaire directly into the computer. The majority chose to enter the judgments in printed versions of the questionnaires and the researcher entered the answers into the software program. When inconsistencies or errors were detected, the researcher contacted the expert to validate the answer. This procedure insures the completeness of all parts of the inquest.

The validity of the method was secured by choosing validated instruments such as the AHP and ECPro software. The cause and effect diagrams were constructed based on a banana production system diagram that was presented in a peer-reviewed journal publication (Hernández and Witter, 1996). The hierarchical structure was assembled from the Cause and Effect diagrams. Consistent validated scales were chosen to standardize the units of measurement. Consistency was checked to ensure that the judgments were within the acceptable limits. The Delphi Method allowed the researcher to review previous expert opinions with the other members of the EP, and the experts made adjustments when inconsistencies, misjudgments or mistakes were recognized.

All measurements are subjected to experimental error, and pairwise comparisons are no exception. The type of inconsistency possible in pairwise comparisons can be better explained by the following example: An expert is asked to compare the value of three panoramic views. The letters A, B and C identifies views. If the judge rates "A" three times better than "B" and "B" two times better than "C", a consistent judgment should rate "A" six times better than "C". However, it is entirely possible in a pairwise comparison between "A" and "C" that the judge rates "A" only four times better than "C". Because of the nature of the problem this inconsistency may be acceptable. On the other hand if "C" is judged better than "A", the researcher may want to discuss the inconsistency and ask the judge to review his assessment. Inconsistencies in judgments in pairwise comparisons are expected, and the amount that can be tolerated depends on the nature of the problem. Therefore, the important issue is to calculate the amount of inconsistency so that the researcher can make a decision whether to accept the judgment or reject it.

Calculating a consistency index (CI), a random consistency number and establishing a consistency ratio (CR) checked consistency in this experiment. The procedure for calculating the CR was amply explained by Saaty and Kearns (1991, p. 33). Furthermore, Saaty and Kearns (1991, p. 34) recommend an acceptable CR of 10%, but cautioned not to discard the possibility of accepting higher values depending on the nature of the problem up to a maximum value of 20%. For this experiment, the following criteria was fixed before the interviews started: all values over 10% must be reviewed with the panel of experts and after review inconsistencies can be allowed up to 20%. Data which does not meet this criteria must be discarded. Since most experts chose to start their analysis by entering percentages and then checking validity by converting to pairwise comparisons, the inconsistencies ratios were kept well below the value of 10%.

3.5 Procedures

3.5.1 Data Collection and Calculations

This section lists all the steps and tasks that were performed to collect and process the data for this project.

1. **Formation of the panel of experts** - A list of names was compiled by asking EARTH's faculty and staff to suggests names of noteworthy experts in banana production. These names were complemented by the authors personal acquaintances within the banana industry. From the list, the researcher chose ten experts and contacted them by phone to schedule a meeting.

2. **First Meeting**

a. A full explanation of the project was given to the candidate and his cooperation was requested. In return, the candidate was promised confidentiality.

b. Each candidate was asked to sign a standard letter of informed consent. A copy was given to the participant and the original was filed with EARTH College's Comptroller to guarantee confidentiality. If any of the candidates refused to give consent, another candidate was chosen from the list and step one was repeated.

c. A number was assigned to each panel member to identify him without violating the confidentiality pledge.

d. The last task of the first meeting was to secure an appointment for the first 90 minute interview.

3. **First Interview**

a. The first step was to allow the panel member to clear any doubts as to his participation.

b. The expert was asked to review the cause and effect diagrams. Comments, additions and corrections were recorded directly on the diagrams. Latter, after carefully reviewing the notes taken, the cause and effect diagrams were amended. Using the Delphi Method of interviews, the revised copy of the cause and effect diagrams were then used to show the next expert. In this way, each expert was allowed to comment on the changes suggested by the other members of the panel. The final version was presented in a meeting of the Environmental Banana Commission. The members of this commission made comments and suggested a few changes, which were introduced to the diagrams.

c. The list of conventional production practices (predictor variables) chosen from a life cycle analysis was reviewed. The description of each task was carefully reexamined, experts volunteered 'hard' data to complement the description, and the list was improved. The improved list was presented to the next expert, giving each expert the opportunity to comment and improve the description of the previous expert.

d. The expert was asked to suggest potentially better practices (SPP) that merit consideration and further research, and a full description of that practice was noted in the space opposite the corresponding CPP predictor variable. Each expert was shown the information given by the previous expert allowing him to complement and add alternative SPP. When available, 'hard' data was added to the description. The final list of SPP was reviewed and summarized by the investigator, a description was prepared, and doubts were checked by phone communication with the experts. For some of the predictor variables there were more than one SPP chosen and in a few cases, the CPP were deemed the best available practice. The compiled list of CPP and SPP predictor variables was used for the assessment in the second interview.

e. Before ending the first interview, a second interview appointment was secured.

4. <u>**Transfer Information to ECPro**</u>

The information gathered was synthesized and loaded into the software package.

5. <u>**Second Interview.**</u>

a. The first step was to allow the panel member to see the results of the first interview in advance of the second meeting.

b. The next step was to meet the each expert and explain once more the procedure for the filling out the evaluation questionnaire.

c. A laptop computer was used to display the AHP structure and the evaluation questionnaires.

Each of the questions was reviewed and the expert was asked to make a judgment.

A few of the experts chose to fill the questionnaire directly in the computer in the presence of the researcher and reasoning each of their answers. This procedure took approximately 3 hours.

Most of the experts chose to go through several of the questions with the researcher, they filled the answers, asked questions and then finished the questionnaires on their own. In this case the interview took approximately 90 minutes.

6. <u>**Transfer Information to ECPro**</u>

a. The answers to the questions were loaded into the ECPro software.

b. The results were checked for consistency. Inconsistent judgments were discussed with the experts to allow him or her to make corrections.

The expert was asked to rate each CPP and SPP predictor variable. Ratings were loaded in ECPro software and results printed.

7. **<u>Data Analysis</u>**

a. The results were arranged in a matrix configuration to facilitate analysis.

b. The data was prepared for statistical analysis and loaded into SPSS.

c. The hypothesis was tested.

8. **<u>Recommendation and Conclusions</u>**

a. From the information gathered, recommendations were made and a strategic plan was formulated to implement them.

3.5.2 Research Method Flow Chart

A flow chart of the procedure described in the previous section is shown in Figure 6.

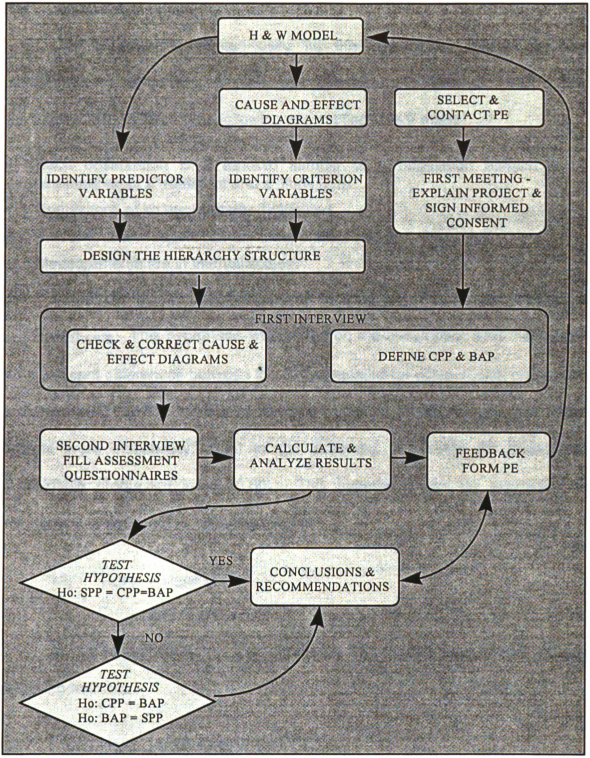

Figure 6 - Methods Flow Chart

3.6 Statistical analysis

The experimental design used for this dissertation was a two-way classification or randomized block design (Snedecor and Cochran, 1967, p.299; Kachigan, 1986, p.301). The following assumptions were made:

- Each observation is a random sample of a population defined by a combination of a treatment and a block (kn).
- Populations of kn are normally distributed.
- Treatments and repetitions are independent and do not interact.
- Measurements are in interval scales.

In order to test the hypothesis it was necessary to state it in the form of the null hypothesis. This hypothesis was based on the assumption that there were no significant differences between the SPI calculated for conventional production practices and the SPI calculated for best available practices, and that these indices were statistically equal to the assumed SPI value for acceptable sustainable production index (0.60). This hypothesis can be expressed in mathematical terms in the following manner:

$$H_0: \quad \mu_{CPP} = \mu_{SPP} = SPP$$

$$SPP = 0.06$$

In mathematical terms the alternative hypothesis was stated in the following manner:

$$H_1: \quad \mu CPP \neq \mu SPP \neq SPP$$

The mathematical model for this two-way classification experimental design was represented by the following formula:

$$Y_{ij} = \mu + \alpha_\iota + \beta_\varphi + \varepsilon_{\iota\varphi}$$

where,

μ	= Overall Mean
α_i	= Treatment (Row) Effect
β_j	= Replication (Column) Effect
ε_{ij}	= Independent Random variable Due to Experimental Error

The treatment and repetition effects are random and cancel out. This is expressed mathematically as follows:

$$\Sigma\alpha_\iota = \Sigma\beta_j = 0$$

The independent random variable due to experimental error can be estimated by choosing the level of acceptable error for this experiment, which was assumed to be 0.05.

In accordance to Snedecor and Cochran (1967, p. 306), the following assumptions were made in order to test this mathematical model:

> *1. "The mathematical form ($\mu + \alpha_i + \beta_j$) implies that the row and column effects are additive."*
>
> *2. "The ε_{ij} are independent random variables, normally distributed with mean 0 and variance σ^2. They represent the extent to which the data depart from the additive model because of experimental error (Snedecor and Cochran, 1967, p. 303)."*
>
> *"The residual sum of squares measures the extent to which the linear additive model fails to fit the data (Snedecor and Cochran, 1967, p. 306)."*

The steps necessary to calculate the differences are expressed in table Table 11:

Table 11 - Two-way Classification Experimental Design

i = Rows j = Columns	Treatment 1	Treatment 2	Treatment 3	Replication Mean Row Mean
Replications or blocks (n):	CPP	SPP	SPP	
1	X_{ij}		0.60	$\bar{x}_1$
2			0.60	$\bar{x}_2$
3			0.60	$\bar{x}_3$
...			0.60	...
n = 10			0.60	$\bar{x}_n$
Treatment Mean = Column Mean	$\bar{x}_{CPP}$	$\bar{x}_{SPP}$	0.60	$\bar{x}_{TOTAL}$

SS = Sum of Squares **T = Total** **c = Column** **r = Row**

$SS_T = \Sigma\, \Sigma(x_{ij} - x)^2$

$SS_c = \Sigma\, n_j\, (x_j - x)^2$

$SS_r = \Sigma\, n_i\, (x_i - x)^2$

SS_{cr} = Residual error sum of square deviations = $\Sigma\, (x_{ij} - x_j - x_i + x)^2$ = SSE

SSE = Sum Square Error or Sum Square Residual

SS_{cr} = Total - Column - Row

The F- test was applied using the following ratios and comparing them to the F charts for 0.05 significance level:

Table 12 - Procedure for ANOVA

Source of Variation	SS	df	Variance	Fraction for F - Test
Treatments	SS_c	c - 1	$s_c^2 = SS_c / (c-1)$	s_c^2 / s_{cr}^2
Repetitions	SS_r	r - 1	$s_r^2 = SS_r / (r-1)$	s_r^2 / s_{cr}^2
Residual	SS_{cr}	(c-1)(r-1)	$s_{cr}^2 = Ss_{cr} / (c-1)(r-1)$	
Total	SS_T	cr -1		

If the null hypothesis is not rejected, there is no need for further testing because there are no significant differences among the data and all three treatments can be assumed equal. If the null hypothesis is rejected, then it is necessary to do further hypothesis testing as follows:

H_o: μ_{CPP} = SPP

H_1: $\mu_{CPP} \neq$ SPP

H_o: μ_{SPP} = SPP

H_1: $\mu_{SPP} \neq$ SPP

SPP = 0.60

To accomplish this testing a Planned Orthogonal Comparison (Kachigan, 1986, pp. 304-311; USDA, 1966, pp.6-14) was used. The table 13 illustrates the procedure.

Table 13 - Procedure for Testing a Planned Orthogonal Comparison

	T1 = CPP	T2 = SPP	T3 = SPP	Dif.	Dif.^{2}	Divisor	Sum of the Squares
Contrast 1 C1	+1	-1	0	XCPP-XSPP		$(+1)^2+(-1)^2*n$	SS_{C1}
Contrast 2 C2	0	+1	-1	XSPP-XSPP		$(+1)^2+(-1)^2*$	SS_{C2}
							SS = SS_T

$$SS_{C1} = \frac{+1\,(CPP) - 1(SPP)}{(+1)^2 + (-1)^2 * n}$$

$$SS_{C2} = \frac{+1\,(SPP) - 1(SSP)}{(+1)^2 + (-1)^2 * n}$$

C1 F-Test = SS_{C1} / SS_T

C2 F-Test = SS_{C2} / SS_T

Limitations and Delimitations

In the analysis of the information resulting from the application of this method, it was necessary to keep in mind the many assumptions that were made and the limitations, which these assumptions impose on the method. The conclusions reached and recommendations made took into consideration these limitations.

Concluding Remarks

The previous sections describe the method used to collect and analyze the data. The foundations of the method used rest on the H & W model which was presented in an article published by the author of this dissertation and Dr. Scott G. Witter in AMBIO and edited in Chapter 2 of this document. However, the model lacks one fundamental element. It does not render precise intensities for each of the interactions shown. The definition of interaction intensities is the instrument necessary to judge sustainable performance. The development of a method to obtain weighted intensities among the different interactions between the environment, society and the economy and the derivation of sustainable performance indices was the fundamental contribution of this dissertation.

The following chapter summarizes the results of applying this method. It arranges the data in an orderly fashion to facilitate analysis and synthesis. The fourth chapter sets the stage for the formulation of recommendations and conclusions.

Chapter 4

RESULTS

4.1 Introduction

The problem and questions to be answered in this dissertation were introduced in the first chapter. Sustainable agricultural production became the beacon to guide the search for solutions. The fundamental pillars that support sustainable agricultural production were recognized as the environment, society and the economy. Systems theory was utilized as the road to detect sustainable solutions. Chapter I introduced world-class banana production system as a specific case to test the validity and appropriateness of the proposed systems method for evaluating the sustainability of ag-production.

The second chapter prepared the road by dissecting, classifying and quantifying the problem through the collection of information available in the literature. It introduced a basic model advanced by Hernández and Witter (1996), that outlines the production system. This model defined the limits, the components, the inputs and outputs, and it evidenced the interactions among the different components of the system. It served as a map that facilitated the search for a sustainable solution. However, it lacked precise intensities for each of the interactions and it did not consider the social and economic elements of the system.

A method to assign intensities and derive performance indicators based on systems theory was proposed in Chapter 3. In essence, this was a decision-making method that had several steps leading to one objective – organizing information to assist producers in identifying and applying the best available method for growing bananas in a sustainable manner.

This chapter presents the results of applying the decision-making process outlined in the previous chapters. It is organized according to the ten consecutive steps that were taken to complete the process. The sections of this chapter discusses each of those steps:

Section 4.2 - Identifies and describes the panel of experts (PE),

Section 4.3 - Defines the conventional production practices (CPP),

Section 4.4 - Lists the alternative production practices (APP),

Section 4.5 - Establishes criteria and standards.

Section 4.6 - Assigns relative weight to the criteria,

Section 4.7 - Rate the CPP and the APP, and calculate environmental, social and economic performance indicators (ENPI, SOPI and ECPI),

Section 4.8 - Rejects the APP that fail the criteria for BAP,

Section 4.9 - Calculates the sustainable performance indices (SPI), and

Section 4.10 - Tests the hypothesis.

Sections 4.3 through 4.5 report the results of the first interview, and sections 4.6 and 4.7 compile the results of the second interview. The rest of the sections give the results of the calculations and statistical analysis.

The following sections contain the facts presented as tables and figures. It also includes the author's description of what is important about the facts and the process of gathering the facts. The discussions of the findings and conclusions are reserved for the next chapter.

4.2 Panel of Experts

A careful search for a balanced PE was a fundamental requirement to achieve adequate results. A total of 18 experts were consulted in the first round of interviews, of which two declined to continue with the study. Twelve of these (PE 1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, and 15) were chosen to fill out the questionnaires based on their holistic knowledge of the industry. Four (PE 2, 6, 14 and 16) were used as consultants in specific areas of this study. Out of these four consultants, one was used as a test run to calibrate the other questionnaires. The pilot questionnaire was discarded because it could not be reconciled with the format of the subsequent questionnaires. Additionally, the expert in reference (PE 2) disqualified himself from emitting opinions regarding social issues because he is a foreign national and did not consider himself to be familiar with Costa Rica's society. It is noteworthy to say that his interview was very valuable. Besides serving to calibrate subsequent interviews and questionnaires, priceless information was derived from the interview that was incorporated into the definition of the environmental criterion used.

Ten (PE 1, 3, 4, 5, 7, 8, 9, 11, 12 and 13) out of the 13 experts chosen to fill out the questionnaire, submitted complete questionnaires. One (PE 15) out of the two remaining experts submitted opinion only in the environmental section of the questionnaire. However, all of the experts were interviewed at least twice and valuable information was gathered from them.

Table 14 enumerates and describes each of the experts and gives details of their participation. To ensure confidentiality, each expert was identified by number and not by their names. Their characteristics are carefully summarized as not to reveal their identity. However, the experts chosen are well known in the industry, the industry is a close-nit group.

Great effort was placed in balancing the PE since the study is based on opinions. Five of the ten experts that completed the questionnaires are directly involved in production of bananas (PE 1, 4, 5, 8 and 11). The remaining five experts are directly involved in support services for the industry, including education of the future managers of the industry, and doing the research and development of many of the alternative production practices (PE 3, 7, 9, 12 and 13). The expert that partially completed the questionnaire is involved in both areas, production and support (PE 15). As will be noted in the appropriate section, there is a significant statistical difference in the resulting indices among the two groups.

Table 14 - Panel of Experts

N#	Description	Participation
1	A national producer that is the owner of a large plantation producing bananas for a transnational buyer.	Pe1 participated in three interviews and completed the evaluation questionnaire. He also supplied his farm's financial data, which combined with the information from two other farms, set the weights for the economic criteria.
2	College professor specializing in tropical crops.	He participated in two interviews and collaborated in the pilot questionnaire. He provided a major portion of the information used to define environmental criteria. He also contributed with several innovative APPs.
3	College professor specializing in tropical crops.	He participated in one interview, reviewed and commented the results of the first interview, and completed the evaluation questionnaire in the presence of the researcher. Each answer was justified orally providing great insight for the researcher.
4	Staff member of a transnational grower-buyer. A biologist and a specialist in environmental and social issues of banana production.	He participated fully in at least three interviews, and completed the evaluation questionnaire. He contributed greatly to the definition of the criterion variables and the CPPs and APPs. His questionnaire was one of two first generation questionnaires, which had a large amount of detail. The experience served to streamline the rest of the questionnaires.
5	Economist in charge of financial affairs for three large independent farms. He worked for many years as a financial officer for a transnational grower-buyer.	He participated in three interviews and completed the evaluation questionnaire. He also compiled and prepared the financial data from three farms, which served to assign weights to the economic criteria.
6	Staff member of a transnational grower specializing in safety and human resources.	He participated in one interview and supplied a major portion of the information used to define the social criteria. He also collaborated in defining the APPs for the social component of the study.
7	Certification NGO that emits environmental labels and specializes in wood, bananas and oranges.	Pe7 consists of a group of three, two agronomists and a lawyer (two females and one male). The group participated in two interviews and completed the evaluation questionnaire. Their questionnaire was one of two first generation questionnaires that had a large amount of detail. The experience served to streamline the rest of the questionnaires.
8	Consultant to several independent producers. Specialist in production practices. Author of several articles in production and environmental issues.	He participated in at least three interviews and completing the evaluation questionnaire. His participation was crucial in the definition of CPPs and APPs.

Table 13 Cont'd

9	Researcher specializing in environmental issues of banana production.	Pe9 participated in at least three interviews and completing the evaluation questionnaire. His participation was crucial in the definition of criterion variables and CPPs and APPs. He also collaborated in streamlining the questionnaires. He completed the evaluation questionnaire in the presence of the researcher. Each answer was orally justified providing great insight for the researcher.
10	National independent producer of organic bananas.	He participated in two interviews and contributed in the definition of criterion variables and in suggesting innovative APPs.
11	Superintendent of several banana plantations. He is directly responsible for productivity and quality of fruit.	He participated in at least three interviews and completed the evaluation questionnaire. His participation was crucial in the definition of CPPs and APPs.
12	Researcher specializing in agronomic issues of banana production.	He participated in at least three interviews and completed the evaluation questionnaire. His participation was crucial in the definition of criterion variables and CPPs and APPs. He also completed the evaluation questionnaire in the presence of the researcher. Each answer was justified orally providing great insight for the researcher.
13	Biologist, environmentalist and consultant to the banana industry.	He participated in one interview, reviewed and commented the results of the first interview, and completed the evaluation questionnaire in the presence of the researcher. Each answer was orally justified providing great insight for the researcher.
14	College professor and an anthropologist.	Pe14 participated in one interview and supplied information used to define the social criteria.
15	College professor and owner of a banana plantation. Author of several books and articles.	He participated fully in at least three interviews, and partially completed the evaluation questionnaire. He contributed greatly to the definition of the criterion variables and the CPPs and APPs.
16	Group of three high level, corporate staff members of a transnational grower-buyer company.	This group reviewed the article published in AMBIO by Hernández and Witter (1996) and the list of CPP APP. They emitted a written opinion. There was one joint interview, in addition to several E-mails, personal and phone conversations with the coordinator of the group to verify details. A major portion of their considerations were incorporated to this document. This information is referenced separately in the document as PE16 because it was obtained through a different procedure than that used to obtain the information supplied by the rest of the experts.

The following three sections present the results of the first interview with the experts. The objective of the first interview was to identify the independent and criterion (dependent) variables. The independent variables are the conventional and the alternative production practices. The dependent variables are the criteria that were used to evaluate the independent variables.

4.3 Conventional Production Practices

The identification of Conventional Production Practices (CPP) was very complex. Few banana production companies in Costa Rica have exactly the same production practices. Transnational growers attempt to standardize practices in their plantation, but different environmental conditions forces customized procedures for each plantation. Furthermore, edafic differences within plantations require adjustments and customized procedures for each section of the plantation. Financial constrains limit a large number of producers in adopting some recommended practices that improve environmental and social performance. These differences contribute to the great disparity in level of sustainable performance among plantations in Costa Rica.

Due to the previous reasons, the definition of conventional production practices was very troublesome. A great amount of time was spent in the interviews rendering a precise detailed base-line definition for CPP. The researcher prepared and presented to the experts a first draft document based on definitions and descriptions made by Sánchez (1996) and Soto (1994). Each of the experts had the opportunity to review this definition and the changes made by the other experts at least twice.

The final definition is a compromised definition and not all experts are in total agreement with every stipulation. Therefore, it is important to note that the description of CPP cannot be generalized and used to describe the standard practices of the industry because they do not exist. Some plantations have a technological package that is similar to the one described in this document, some apply more advanced practices and some have a less sophisticated package. The description of CPP is only a benchmark definition to compare with the alternative production practices.

On the left side of Table 35 in Appendix B, the CPP have been categorized by type of activity, each of the practices was assigned a number and described at length. The activities were divided into three categories: Production (identified by numbers ranging from one through six), Labor Management Practices (identified by the number seven), and Macros (identified by the number eight). The first category was subdivided into Field Practices (numbers ranging from one to five) and Packing Practices (number six). Each subdivision was further subdivided and assigned letters. The Labor Management category (seven) was subdivided into Hiring Practices (a), Fringe Benefits (b), Risk Prevention (c) and Others (d). The experts were issued a final draft copy of Table 35 in Appendix B in Spanish as a reference for use in assigning ratings and filling the questionnaire. A few changes were made in the final English version of the document in response to comments made during the evaluation. These modifications did not change the basic definition, but made it precise.

The definition of the CPP completed the first objective of the initial interview. The second objective was to compile a list of alternative production practices that after careful analysis and evaluation could be considered best available practices (BAP). The following section presents the list and description of the suggestions given by the experts.

4.4 Alternative Production Practices

The PE was asked to identify and define the APP. Each expert had at least two opportunities to review the list of APP and the changes made by the other experts. Even if the majority of the experts were not in agreement with one or more of the suggested alternative practices, none of the suggested APP were removed from the list. The APP were not considered best available practices (BAP) until the results were analyzed and statistically tested against basic criteria. The experts had the opportunity to voice their opinions of the APP through their ratings. Some recorded their opinions in writing. The alternatives with low ratings, as well as those that were not fully available at the time of evaluation, were rejected from the list of BAP. Many of the APP were already in use in some plantations. Others were not fully tested and require pilot field trials before industry-wide acceptance. The experts were quick to point out which were tested and which were not. Careful note was taken of their opinion and it was used to discard APP with high ratings, but that were not available at that time.

On the right side of Table 35 in Appendix B, the APP suggested by the experts were recorded and organized using the same categories and sub-categories that were established in the previous section. Each was assigned a number and described in length. Since the categories and sub-categories for the CPP and APP coincide, the right side of Table 35 in Appendix B exhibits the alternative practices for the CPP shown on the opposite side. It is important to note that several of the APP apply for multiple categories and were evaluated in more than one category. The members of the PE were supplied with a Spanish version of this table as a reference to assign ratings and fill the questionnaire. No changes in the description of the APP were made in the English version of the table.

The method proposed in Chapter 3 calls for the creation of an evaluation matrix to rate the CPP and APP. The list of CPP and APP completes the vertical axis of the evaluation matrix. The next task is to designate the criterion variables that constitute the horizontal axis of the matrix and become the headings of the columns. The application of any of the production practices (the rows of the matrix) will have an effect on the environment, the people and the economy (the columns of the matrix). The purpose of the next section is to identify the criteria to evaluate the effect caused by the production practices.

4.5 Criterion Variables

Figures 15 through 36 in Appendix A represent cause and effect diagrams (fishbone diagrams) that are generic to any agricultural production activity. The difference is in the inputs, which are specifically tailored to represent the production of world-class bananas. The boxes in these diagrams are used to designate the criterion variables at three levels of detail – mega, macro and micro. Some of the micro criteria were further subdivided to show more detail. The shaded boxes show the level of detail included in this study.

These diagrams were assembled with the help of the PE. The author constructed an initial set of diagrams that were shown to a major segment of the PE (15 experts) on an individual basis. Each of the experts contributed to the diagrams, and his contribution was included in the diagrams shown to the expert in the following interview. Using the Delphi method, all experts had the opportunity to comment and contribute to the diagram at least twice. The Environmental Banana Commission (CAB)[15] also reviewed the diagrams and made suggestions. The final version of the cause and effects diagrams was a compromise among the experts. In contrast to the definition of the CPP, in this case there was general agreement by the PE.

Due to the complexity of the system, it was impossible to draw one general diagram. It was necessary to create a cascade of diagrams that proceed from the macro to the micro components of the system. In essence, the components of the diagrams are the dependent variables of the system. This means that any production activity (independent variables) occurring within the system has an effect on all the components shown on the diagrams (dependent or criterion variables). Some of the effects are direct, yet others are indirect and less obvious.

The arrows shown in the diagrams (Figure 15 through 36 in Appendix A) depicted vectors. The mathematical dimension of the vector (the arrows in the diagrams are not drawn to scale) was a product of the intensity (relative weights assigned by the PE - see section 4.6) multiplied by the rating of performance (see section 4.7). The direction of the arrows showed whether the effects were beneficial (+) or detrimental (-). Vectors that point to the right showed beneficial effects and vectors that point to the left showed negative effects. The performance index was the resulting vector, which was the sum of all the impact vector. Since the ECPro software does not permit positive and negative numbers, a scale of zero to one was chosen. A rating of 0.6 was defined as the acceptable level or the fulcrum point between positive and negative effects. Numbers above this point show positive effects and numbers below show negative effects. A rating of 0.6 indicates a balance between negative and

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[15] CAB is a multidisciplinary group of experts representing all the banana industry's stakeholders in Costa Rica whose objective is to recommend environmental policy for the industry.

positive forces, which was the minimum expected condition of any of the activities in order to be acceptable.

Following suggestions from the Environmental Banana Commission and some of the experts, the main headings were chosen to indicate positive performance, in an effort to set a constructive note to the study, and not to antagonize the producers. For example, instead of using the term "Pollution Generation" to indicate a criteria, the term "Pollution Prevention" was used.

The cause and effect diagrams were used to revise and complete the H&W model proposed in Chapter 3. Figures 37, 38 and 39 in Appendix A illustrate the revised model. The most significant change was the addition of the social and economic elements to the model. Each element of the system was sketched in a different figure. The combined drawing depicts a banana production system. Notwithstanding the importance of the intimate interconnection of the three elements of the system, no interactions or feedback loops were shown that links the three diagrams. The interconnection was recognized but not shown in order to simplify the diagrams. Intensities were only shown for the economic model since the values were a product of hard data. Intensities for the other two components are the subject of section 4.6.

The diagrams defined the limits of the system by enclosing the components (the banana plantation and the packing plant) within a curve edge rectangle. The vectors within the limits of the system represent the interactions among the components of the system. The arrows outside the limits evidenced the inputs and outputs of the system.

The components shown in the cause and effect diagrams were used to build the hierarchical structure essential to the ECPro software. For the pilot questionnaire, the hierarchical structure included five levels of detail. The resulting evaluation matrix was very large and it required too much time to complete each of the three questionnaires (environmental, social and economic). Since the experts could not be expected to invest this amount of time in completing the questionnaires, it was necessary to reduce the levels of detail. Two modified questionnaires were prepared and presented to PE 4 and PE 7. The time requirements were reduced to eight hours to complete the three questionnaires. After consultation with several of the members of the PE, it was decided to reduce the level of detail even more. The shaded boxes shown in the diagrams depict the level of detail and the criterion variables included in the hierarchical structure and final questionnaires. The amount of time necessary to fill the final questionnaires was three hours. This time requirement exceeded the commitment made to the members of the PE in the letter of informed consent. Ten members of the PE, agreed to continue their participation, one completed only one of the three questionnaires, and one dropped out of the study.

It is important to recognize that the dependent variables are not independent of each other. They are interconnected by feedback loops. The model becomes very complex if feedback loops were considered and lose clarity. Therefore, the cause and effect diagrams only considered direct relationships, and ignored indirect relationships (feedback loops). As a consequence, the resulting hierarchical structure digitized into the ECPro software had no feedback loops incorporated into it. It is significant to note that the software used has the capacity to include feedback loops. However, the size and complexity of the questionnaires is augmented beyond manageable levels.

At this stage, the objectives of the first interview were accomplished. The second interview had two objectives: define the intensities of the criterion variables and rate the CPP and APP. As indicated before, the arrows shown on the diagrams depicted vectors and the value of the vector depended on the intensity and the rating. The intensity of a vector was synonymous to the importance of the criterion variable. The objective of the next section was to present the set of values (weights) that were given by the PE to each of the criterion variables chosen for the evaluation matrix.

4.6 Relative Weights (Intensities)

From the results obtained in the pilot run (PE 2), it was evident that the degree of importance for each of the criterion variables varies according to the activity that was being analyzed. Furthermore, activities could be grouped according to type, and each type of activity had a different degree of effect on the sustainability of the system. For this reason, the activities shown on table 35 in Appendix B were arranged according to categories and sub-categories forming a pyramidal hierarchical structure. This structure was subdivided forming two pyramidal hierarchical structures with two levels of analysis. Borrowing from civil engineering structural terms, the higher hierarchical structure was referred to in this document as the superstructure (SS) and the lower hierarchical structure as the foundation structure (FS). The lower structure was used to calculate the individual ENPI, SOPI, and ECPI for each expert and each category of activities. The average value of the index (ENPI, SIPI and ECPI) for each expert and category was plugged into the SS structure to calculate the aggregated sustainable performance index (SPI).

It was necessary to divide the hierarchical structures into two structures because the ECPro software allows for only five hierarchical levels, and at least six levels were necessary to analyze the system in a single hierarchical structure. Furthermore, the separation into two hierarchical structures permitted calculation of environmental performance indices (ENPI), social performance indices (SOPI), and economic performance indices (ECPI) individually for each of the CPP and APP. This allowed the analysis of each activity before aggregating into a collective index (SPI). If the single structure had been used, the calculation of the SPI would have been done in one step without reporting the intermediate values.

Figure 9 illustrates the FS for the environmental component, figure 10 Illustrates the FS for the social component, Figure 11 Illustrates the FS for the economic component of the system, and Figure 12 represents the SS. The components of the FS correspond to the lowest level of detail (micro level) criterion and sub-criterion variables that were presented in Figure 15 through 36 in Appendix A. Each activity was rated using these bottom line criterion variables. The rating scale was shown on the right side of Figure 7 and 9. In Figure 8, the rating scale was substituted by the word “ratings” for reasons of space in the drawing.

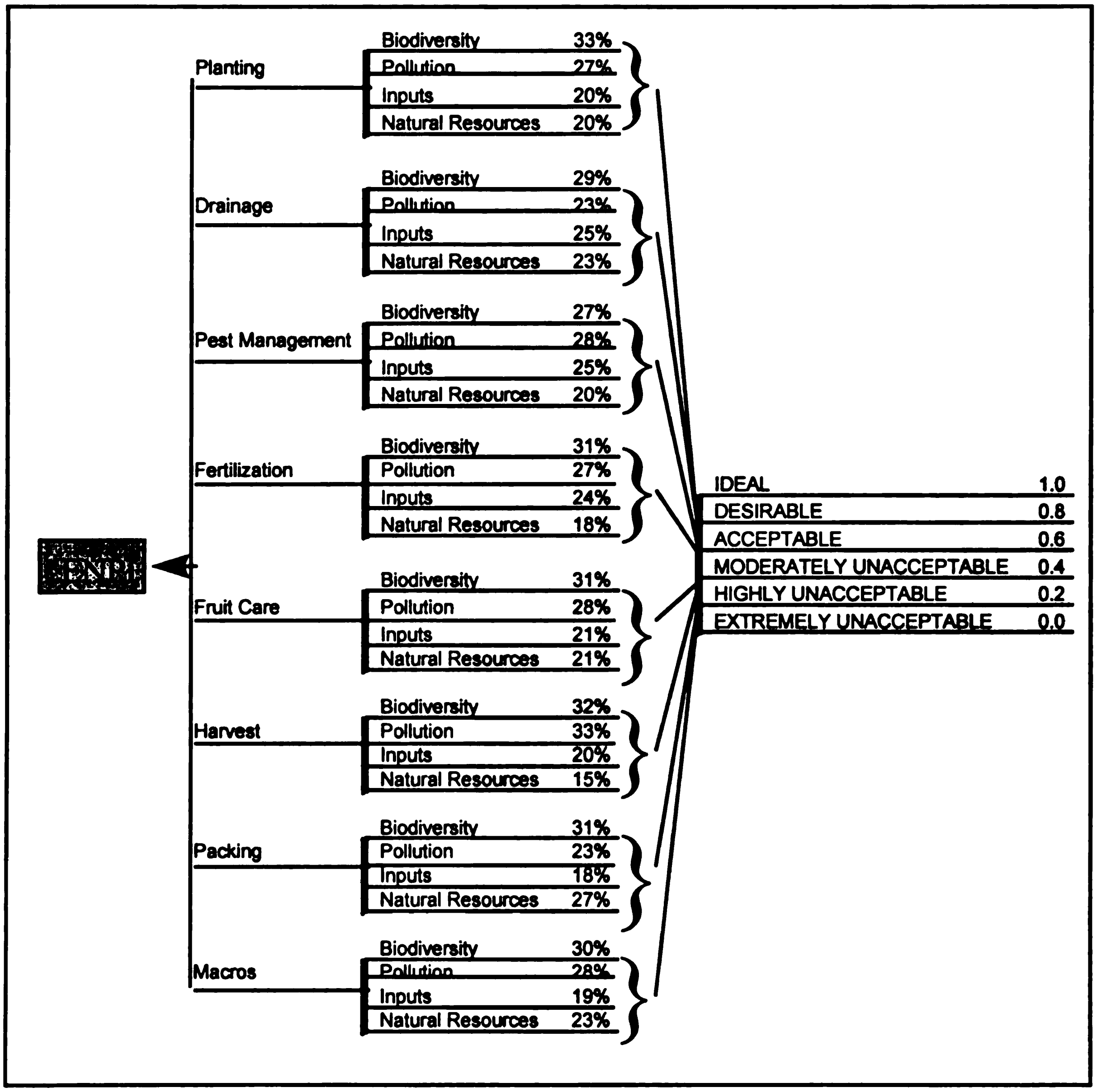

Figure 7 - Foundation Structure for the Environmental Component

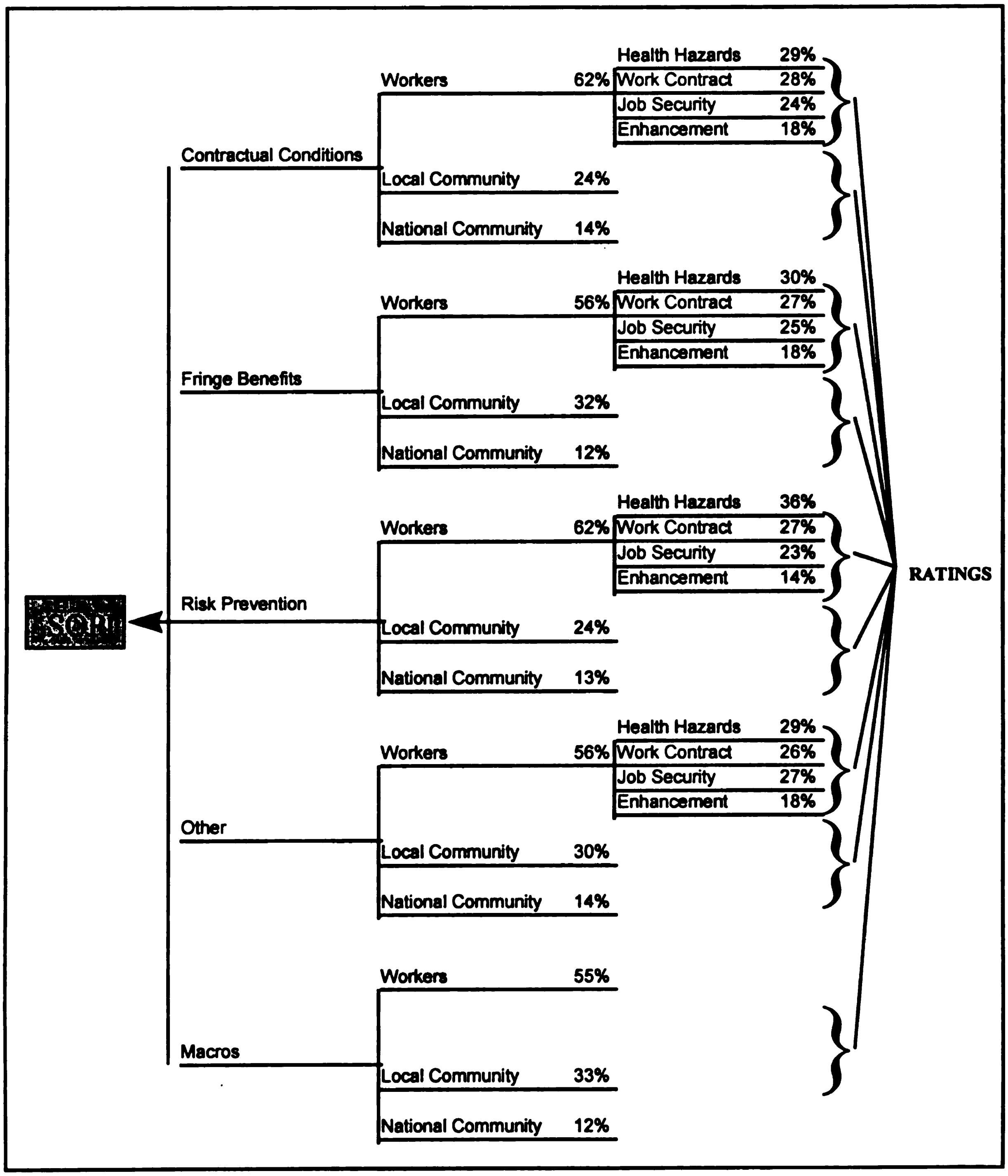

Figure 8 - Foundation Structure for the Social Component

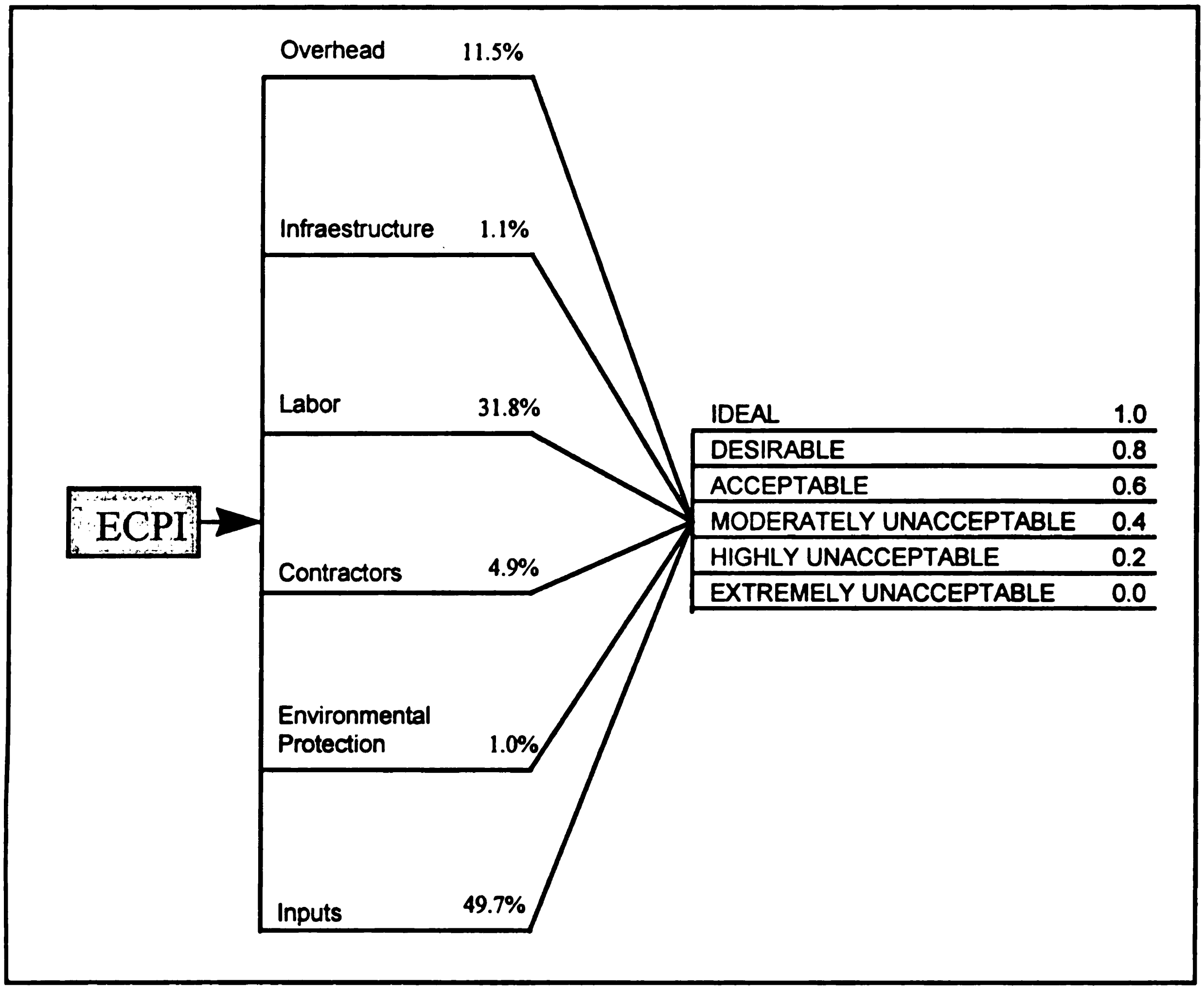

Figure 9 - Foundation Structure for the Economic Component

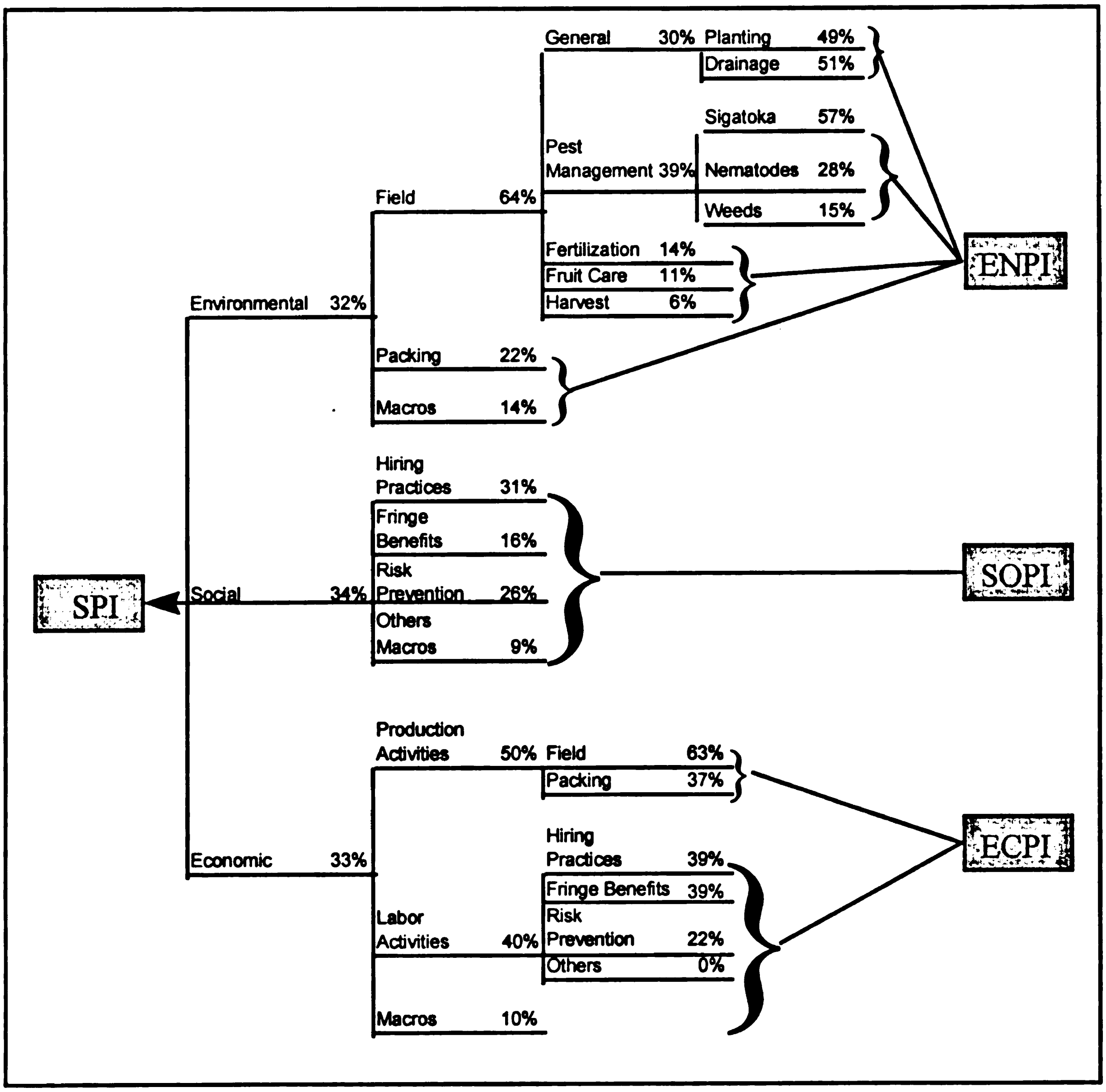

Figure 10 - Superstructure for the Production System

Table 36 and Table 38 in Appendix B show the individual weights given by the PE for each category and criteria. The individual weights were used to calculate the individual indices for each expert. The data evidences a wide range of values. For this reason, it was judged necessary to identify outliers and eliminate them. The statistical analysis of the data was made at three confidence intervals (95%, 90% and 75%), setting limits at both tails-ends of the normal distribution curve. A 75% confidence level was chosen after analyzing the outliers. With this level of confidence, only one or two extreme values were rejected. However, there are a few exceptions where more than two values were rejected. The majority of the resulting mean values differ by only a few percentile points from the mean values calculated using the entire data set. The maximum variation was 7%. Table 36 and Table 38 in Appendix B show the individual weights given by the PE for each category and criteria. The individual weights were used to calculate the indices.

The average weights have no bearing on any of the numbers used to test the hypothesis. However, the average weights show general tendencies and help define the importance of the interactions among elements of the model, which was one of the objectives of this dissertation. Figures 7 and 8 show the mean intensities as percent values for the environmental Foundation Structure (FS) and the social FS. The economic intensities were derived from hard data generated from the 1996 financial reports from three farms, and are shown in Figure 9. The weights or intensities given by the PE to the elements in the SS are shown in Figure 10.

In reference to Figure 10, the results show that the weight given by the experts to the three principal components of sustainability – environmental, social and economic – were approximately equal. Within the environmental component, the field activities predominated with 64% of the weight. Of the field activities, pest management received the highest weight (39%), followed by general practices (30%). Judging from the results, there was no doubt in identifying the control of black *Sigatoka* as the most impacting practice on the environment, followed by drainage and planting practices. Within the social component of the system, hiring practices was the highest priority given, closely followed by risk prevention practices. Within the economic component, production activities were the most important elements, followed by labor activities.

At this point, the vertical and horizontal axis of the evaluation matrix were finalized and the first objective of the second interview was accomplished. The next step was to fill the cells of the matrix by rating each CPP and APP with respect to the criterion variables. The experts were asked to fill questionnaires and rate the impact of each of the production activities. The objective of the next section is to report the results of the evaluation ratings given by the experts.

4.7 Ratings

The instrument for rating the CPP and APP was a questionnaire containing the evaluation matrix. This matrix was subdivided into three major matrixes – the environmental, social and economic evaluation matrixes. A large volume of data was generated. The tabulated data was not included in this section because it requires reduction and synthesis for it to be meaningful. This section includes the author's description of what is important about the process of gathering the facts and reducing them to meaningful indices.

Ideally, all of the production and labor practices should be evaluated in each of the components of the system (environment, social and economic). As a result of experiences derived from the pilot questionnaire, it became evident that the experts can rate only direct effects of the CPP and APP with a good degree of confidence and consistency. For example, production activities, such as planting and population control, drainage or fertilization, have direct effects on the workers primarily in health hazard prevention but not on the other criteria and sub-criteria (for example Benefits to the Local Community). Therefore, the expert doing the rating was not clear on how to rate the activity with respect to indirect relationships and it was difficult to cross check all criteria.

To solve this problem, the researcher decided, after consultations with the experts, that all salary and risk prevention measures for field activities be separated and placed under labor related issues and evaluated in the social evaluation matrix only. In this manner, all labor related issues were held constant while rating production activities with respect to environmental criteria, and all environmental issues were held constant while rating labor related activities with respect to social criteria. As a result, labor related activities are not rated in the environmental evaluation matrix, and production practices are not rated in the social evaluation matrix. In the case of the economic evaluation matrix, all production and labor practices were rated under the same economic criteria.

Using the environmental evaluation matrix, a total of 87 production activities were rated against four criterion variables: Conservation of Biodiversity, Pollution Prevention, Rational Use of Inputs and Conservation of Natural Resources. Since the intensities of each category of activity were different, it was necessary to prepare different matrices for each group of activities. As a result, eight environmental evaluation matrices were prepared each representing one of the following categories of activities: Planting and Population Control, Drainage, Pest Control, Fertilization, Fruit Care, Harvest, Packing and Macros (See figure 7 in section 4.6). The category Macros was used primarily to compare in a general manner the performance of conventional practices against the possibility of abandoning the production of bananas.

The social evaluation matrix served to rate 46 labor related activities with respect to three major criterion variables: Benefits to Workers and Families, Benefits to the Local Community, and Benefits to the National Community. The criteria Benefits to Workers and Family was further subdivided into four sub-criteria: Health Hazard Prevention, Work Conditions and Benefits, Job Security, and Workers Enhancement (improvement through experience and training) (See figure 8 in section 4.6).

The economic evaluation matrix was used to rate 131 activities. These included 85 production activities, 44 labor related activities and two macro activities common to both, production and labor issues (See figure 9).

As stated in the methods chapter, the scale used to rate the production practices was from zero to one; zero being an extremely unacceptable impact and one being an ideal impact. An acceptable impact was set 0.6. In the majority of cases, the experts omitted the decimal point. This was not a problem except with the rating of 0.1 and one. In several occasions, the researcher had to recheck the ratings with the experts to verify the numbers.

As stated in the methods chapter, the CPP economic ratings were assumed as acceptable and were assigned a rating of 0.6. The APP were rated according to the cost increment or deduction. Cost increments necessary to apply the APP were assigned values below 0.6 and in accordance with their severity. Cost deductions were assign values above 0.6.

Each of the experts was asked to fill a set of 14 evaluation questionnaires with 4950 judgments per expert. Out of 12 full sets of questionnaires distributed, 10 were returned completed, one expert returned the set partially filled, and one expert dropped out of the study. Four out of the ten experts preferred to fill the evaluation matrices (questionnaires) in the presence of the researcher and offer reasons for their ratings. This process was very enriching, and the preferred method. Due to limitations of time, six of the experts preferred to fill the questionnaires at their convenience. Out of this group of six, three questionnaires indicated problems that required at least one additional interview and corrections.

A review of the tabulated results evidenced a few empty matrix cells. Some cells were left open because the expert did not wish to give an opinion and some because of error. The researcher had feedback interviews with three of the ten experts to correct problems. One of the experts, which left a block of cells without filling was not available for consultation. As a result one percent of the individual ENPI, SOPI, and ECPI could not be calculated. The effect was that 8.8% of the average indices had to be calculated with less than ten expert opinions. With one exception, all averages were calculated with at least nine expert opinions.

Due to paste and copy error by the researcher, activity APP7cj – "Observance of Re-entry Period" was left out of seven of the questionnaires, and the resulting average was judge not representative of the PE. For this reason, it was excluded from the list of BAP. This was an unfortunate mistake because of the activity's importance.

The empty cells had very little consequences in the final analysis because approximately half of the APP with empty cells were rejected as BAP through statistical analysis. The other half had very little effect because the procedure required the determination of average ENPI, SOPI and ECPI values for each category of activities. In the case that an individual index could not be calculated for lack of information, averages were calculated with the available indices.

None of the averages were calculated with less than nine indices. These average values were substituted into SS to calculate the aggregated sustainability performance index (SPI). As a result, the experimental design with three treatments and ten repetitions (expert opinions) was maintained intact.

After the completion of this step, sets of intermediate indices were available for summary, analysis and testing. To calculate the SPI for the BAP (SPI_{bap}), it was first necessary to determine a tentative list of BAP. The next section presents the list of BAP and details of the statistical procedure used to reject APP that did not meet the criteria.

4.8 Definition of BAP

The following criteria were applied to judge an APP worthy of being a best available practice: the alternative practice must be better than the conventional practices that are being used today, and they must be available for immediate application. Furthermore, a best available practice must be environmentally, socially and economically acceptable individually and holistically. Since a data set of ENPI, SOPI and ECPI was compiled in the last step, It was possible to perform a one tail student-t test to determine which of the APP did not meet acceptable levels of the performance indices. According to the scale established for this study, an activity must have indices above 0.6 for it to be acceptable. Therefore, the hypothesis for this analysis was as follows:

H_o: $\mu_{app} = 0.6$

H_1: $\mu_{app} < 0.6$

A significant level of 0.05 was chosen for this analysis. Table 15, 16 and 17 show the activities that were rejected as BAP under environmental, social and economic criteria respectively. These tables also show the indices calculated for each expert opinion, the mean value, the standard deviation, the calculated student-t for 0.6, and the reference student-t for a significance level of 0.05 and corresponding degrees of freedom. Activities that were below the values of student-t for 0.6 at the chosen significant level were rejected. It is important to note that APP 8 – abandon banana production for export purposes – received the lowest social rating (highly unacceptable).

As stated earlier, the best available practices must be environmentally, socially and economically acceptable not only individually but also holistically. To meet this criteria, the ENPI, SOPI, and ECPI were combined using the weights assigned by the experts for the environmental, social and economic elements of the system. This procedure yields an SPI for each activity, which is designated as the individual sustainability performance index (ISPI). The test becomes more stringent because the aggregation changes the shape of the distribution curve, maintaining the mean but making the curve narrower. As a result, the range of values in the no reject area is narrower. The results of this test are shown on Table 18.

Table 15 - Rejected Alternative Production Practices Based on Low ENPI

APP	ENVIRONMENTAL PERFORMANCE INDEXES (ENPI) EXPERT NUMBER												ST DD EV	STD ERR	0.60 T-STU (2)	T-STU CK
	1	3	4	5	7	8	9	11	12	13	15	Mean				
1aa	0.60	0.16	0.56	0.72	0.43	0.48	0.44	0.22	0.52	0.600	0.61	0.49	0.17	0.05	-2.25	-1.81
2ai	0.64	0.33	0.53	0.60	0.34	0.65	0.20	0.52	0.58	0.400	0.51	0.48	0.15	0.04	-2.70	-1.81
2cf	0.18	0.35	0.55	0.43	0.55	0.50	0.74	0.10	0.56	0.500	0.40	0.44	0.18	0.05	-2.93	-1.81
4af	0.60	0.30	0.27	0.68	0.55	0.52	0.73	0.60	0.20	0.600	0.00	0.46	0.23	0.07	-2.03	-1.81
4bd	0.27	0.45	0.21	0.26	0.57	NO	0.80	0.24	0.45	0.800	0.60	0.46	0.22	0.07	-1.92	-1.83

Table 16 - Rejected Alternative Production Practices Based on Low SOPI

APP	SOCIAL PERFORMANCE INDEXES (SOPI) EXPERT NUMBER											STD. DEV.	STD. ERR.	0.600 T-STU (2)	T-STU CHECK
	1	3	4	5	7	8	9	11	12	13	Mean				
8	0.10	0.30	0.36	0.00	0.39	0.20	0.19	0.10	0.20	0.10	0.19	0.13	0.04	-10.2	-1.83

Table 17 - Rejected Alternative Production Practices Based on Low ECPI

APP	ECONOMIC PERFORMANCE INDEXES (ECPI) EXPERT NUMBER											STD. DEV.	STD. ERR.	.600 T-STU (2)	T-STU CHECK
	1	3	4	5	7	8	9	11	12	13	Mean				
2ac	0.50	0.40	0.58	0.50	0.62	0.40	0.62	0.48	0.60	0.50	0.52	0.08	0.03	-3.00	-1.83
2cd	0.64	0.39	0.58	0.10	0.59	0.31	0.45	0.14	0.63	0.40	0.42	0.20	0.06	-2.88	-1.83
3h	0.41	0.54	0.73	0.35	0.61	0.44	0.65	0.31	0.65	0.50	0.52	0.14	0.05	-1.85	-1.83
3i	0.41	0.50	0.71	0.35	0.61	0.33	0.67	0.31	0.69	0.50	0.51	0.16	0.05	-1.92	-1.83
4ae	0.33	0.48	0.53	0.34	0.60	0.64	0.55	0.43	0.45	0.60	0.50	0.11	0.03	-3.11	-1.83
4ba	0.41	0.50	0.61	0.62	0.57	0.41	0.63	0.50	0.60	0.60	0.54	0.09	0.03	-2.07	-1.83
4bc	0.30	0.31	0.61	0.32	0.57	0.40	0.57	0.40	0.45	0.60	0.45	0.13	0.04	-3.69	-1.83
4bd	0.41	0.48	0.59	0.23	0.58	0.43	0.56	0.41	0.50	0.60	0.48	0.11	0.04	-3.41	-1.83
4bg	0.51	0.55	0.66	0.45	0.60	0.53	0.58	0.51	0.57	0.60	0.56	0.06	0.02	-2.40	-1.86
5b	0.25	0.61	0.66	0.44	0.57	0.50	0.54	0.36	0.6	0.50	0.50	0.12	0.04	-2.47	-1.86
6i	0.41	0.61	0.61	0.31	0.56	0.40	0.64	0.31	0.61	0.60	0.51	0.13	0.04	-2.25	-1.86
6j	0.45	0.56	0.63	0.43	0.58	0.54	0.57	0.50	0.62	0.60	0.55	0.07	0.02	-2.44	-1.86
7ch	0.35	0.30	0.70	0.55	0.59	0.53	0.56	0.53	0.60	0.40	0.51	0.12	0.04	-2.33	-1.83
7ck	0.41	0.54	0.68	0.45	0.60	0.50	0.52	0.60	0.54	0.50	0.53	0.08	0.03	-2.66	-1.83
7cp	0.50	0.56	0.59	0.51	0.60	0.53	0.56	0.61	0.57	0.50	0.55	0.04	0.01	-3.59	-1.83
7cs	0.48	0.58	0.63	0.48	0.60	0.58	0.6	0.50	0.60	0.60	0.60	0.06	0.02	-1.94	-1.83
7cu	0.43	0.45	0.63	0.33	0.00	0.49	0.49	0.42	0.60	0.50	0.43	0.18	0.06	-3.01	-1.83
7cx	0.60	0.58	0.73	NO	0.60	0.49	0.60	0.70	0.53	0.40	0.52	0.10	0.03	-2.31	-1.86

Table 18 - Rejected Alternative Production Practices Based on Low ISPI

APP	INDIVIDUAL SUSTAINABLE PERFORMANCE INDEXES (ISPI) EXPERT NUMBER											STV. DEV.	STD. ERR.	.600 T-STU (0.6)	T-STU CHECK
	1	3	4	5	7	8	9	11	12	13	Prom.				
2aa	0.56	0.45	0.56	0.58	0.50	0.59	0.49	0.64	0.52	0.60	0.55	0.059	0.019	-2.73	-1.83
2ac	0.61	0.42	0.55	0.63	0.54	0.52	0.53	0.50	0.54	0.57	0.54	0.057	0.018	-3.20	-1.83
2ai	0.57	0.49	0.64	0.60	0.48	0.57	0.43	0.57	0.59	0.50	0.55	0.064	0.020	-2.73	-1.83
2aj	0.61	0.64	0.63	0.64	0.49	NO	0.63	0.54	0.55	0.33	0.56	0.100	0.033	-1.18	-1.86
2cf	0.31	0.50	0.58	0.59	0.58	0.50	0.68	0.36	0.62	0.50	0.52	0.115	0.036	-2.15	-1.83
4bd	0.42	0.51	0.46	0.42	0.58	NO	0.67	0.42	0.52	0.67	0.52	0.101	0.034	-2.43	-1.86
5b	0.44	0.51	0.58	0.53	0.59	0.56	0.57	0.46	0.61	0.63	0.55	0.064	0.020	-2.59	-1.83
8	NO	0.43	0.47	0.31	0.59	NO	0.51	0.43	0.61	0.40	0.47	0.099	0.033	-3.98	-1.94

As evidenced in the preceding tables, five APP were rejected under environmental criteria, one under social criteria, 18 under economic criteria, and one that was not previously rejected by using the ISPI. One activity, the incineration of plastic twine (APP 4bd), was rejected under environmental and economic criteria.

Some of the activities rejected because of economic criteria merit review because they are critical for compliance with the law, or because the results seem irrational. Table 19 show these activities.

In addition to the activities rejected by statistical test, some activities were rejected because, according to the experts directly involved in production of bananas, these activities are not available at the present time. Table 20 lists these activities. The APP in this list show promising signs but have not been fully tested in the field, and the risks of application without exhaustive testing are beyond justification and acceptance by the producers.

Table 19 - Rejected Activities that Merit Review.

APP #	SUMMARY DESCRIPTION
6j	Deposit the reject bananas that cannot be used for industrial production in trenches.
7cp	Mark areas of herbicide application with labels indicating the date of application and the re-entry period.
7cs	Improve hygiene practices (frequent hand washing, prohibition of food consumption during activities involving handling of bags, prohibition of smoking).
7cx	Use spraying chambers in the packing plants to prevent worker exposure.

Table 20 - APP Rejected Because of Unavailability.

APP N°	SUMMARY DESCRIPTION
2ad	Use biological controls for prevention (i.e., enhanced microorganisms - EM) and treatment (i.e., *Serratia* that attacks the cell wall of fungi).
2ba	Use biological products: a. *Paecilomycis* b. Plants that attract and trap nematodes, such as *Crotalaria.* c. Biological products (enzyme extracts and natural antagonistic substances) that are safer to workers and to the environment. The leachate from organic decomposition is an organic material that has recently proven in laboratory tests (CORBANA) to be successful in combating nematodes.
2bc	Apply systemic nematodes applied directly to the stump of the mother plant. The daughter absorbs the nematicide and transports it to the roots. It is necessary to investigate the level of exudation from the roots and the possibility of damaging beneficial microorganisms. In addition, it is necessary to verify that there are no residues in the fruit.
2bd	Apply nematicides directly to the roots by means of a hole made with a spike, into which a gel capsule is inserted. The hole is then covered with soil.
4ag	Use reusable bags made of mosquito netting (15 to 20 uses per bag). The fruit must be covered for only 3 weeks of its growing cycle.
6f	Use reusable pallets, made with recycled material that is recycled once it has lost its operational capability.
7aa	Introduce a system of plots assigning all the labor to a group without specialization.
7cq	Substitute the clorpyrifos in the plastic bags with insecticides that are less toxic to humans (cypermetrynes).

The last requirement to establish the list of BAP is to verify that the CPP are not acceptable, and require better practices. If the CPP are acceptable, then the alternative practice must offer a considerable advantage. The same procedure and parameters were used for testing CPP that were used for testing the APP.

The hypothesis for this analysis is as follows:

Ho: $\mu_{app} = 0.6$

H1: $\mu_{app} < 0.6$

Table 21 lists the CPP that were rejected for having indices lower than 0.6. It is important to note that all the CPP that were tested against the environmental criteria were rejected, which means that the PE judged them environmentally unacceptable. All the CPP, that were tested for social criteria fail to be rejected by the statistical test. This means that the PE assigned ratings to the conventional labor management practices that were equal or above the acceptable rating of 0.6.

Table 22 and 23 lists the BAP for production practices and labor management practices with their number and a summary description of each activity. Some of the best available practices were similar and were common to two or more categories of activities. One, two or three asterisks noted these practices. Activities that were given one asterisk correspond to the creation of buffer zones, two asterisks correspond to the establishment of cover crops, and three asterisks correspond to the use of organic fertilizers and soil amendments. Many plantations in Costa Rica have technological packages that include a large number of the practices included in Table 22 and 23. All of the practices included in BAP list are presently being used in at least one plantation in Costa Rica.

Table 21 - CPP with Unacceptable Levels of Performance

CPP	ENVIRONMENTAL PERFORMANCE INDICES (ENPI) EXPERT NUMBER												ST D. DEV.	STD. ERR.	.60 t-STU (2)	t-STUCK
	1	3	4	5	7	8	9	11	12	13	15	Mean				
1a	.600	.270	.496	.600	.413	.600	.290	.200	.364	.280	.416	.412	.15	.04	-4.28	-1.81
1b	.600	.420	.559	.600	.515	.600	.550	.480	.465	.600	.451	.531	.07	.02	-3.37	-1.81
2a	.600	.200	.515	.600	.430	.600	.200	.280	.209	.200	O	.383	.18	.06	-3.74	-1.83
2b	.600	.220	.463	.600	.361	.600	.240	.100	.309	.200	.138	.348	.19	.06	-4.39	-1.81
2c	.600	.200	.460	.600	.363	.600	.200	.800	.314	.200	.163	.409	.22	.07	-2.93	-1.81
3	.600	.265	.391	.600	.584	.600	.300	.600	.325	.200	.258	.429	.17	.05	-3.39	-1.81
4a	.600	.240	.210	.600	.487	.600	.540	.440	.150	.200	.227	.390	.18	.06	-3.76	-1.81
4b	.600	.275	.550	.600	.544	O	.460	.440	.150	.400	.380	.440	.15	.05	-3.47	-1.83
6	.600	.545	.522	.600	.551	.600	.400	.600	.230	.600	O	.525	.12	.04	-1.96	-1.83
8	O	.300	O	.320	.600	.220	.420	.320	.275	.500	O	.369	.13	.04	-5.72	-1.94

Table 22 - Best Available Production Practices

N°	SUMMARY DESCRIPTION
	FIELD PRACTICES GENERAL PRACTICES **Planting and Control of Population –**
1ab	Divide the area of production into 11 parcels and totally renew one parcel per year.
1ac	Rotate areas that do not meet the minimum established level for efficient productio and keep these areas in fallow for at least one year.
1ad	To renew the areas in production, plant the seedlings in bags of compost and-or bokashi (4 kg per bag).
1ae(*)	Reforest the banks of rivers, streams, springs and along roads with quick growing species of medium height.
1af(*)	Create a buffer zone at least 15 m wide around the perimeter of the plantation.
	FIELD PRACTICES **Drainage**
1ba	Design rational drainage system using engineering methods.
1bc	Plant renovated areas by shaping the floor of the plantation into domes to improve the system of superficial drainage.
1bd (**)	Plant and maintain a cover crop on the floor of the plantation.
1be	Construct sediment traps in the secondary and tertiary canals.
	PEST MANAGEMENT **Control of Black *Sigatoka***
2ab	Introduce monitoring techniques for prediction and methodology for decision making based on the ecology and biology of the plantation, the characteristics of the fungus, and climatic conditions.
2ae	Use a helicopter to spray fungicides in specific places where an airplane is not effective or could cause problems.
2af(*)	Reforest a minimum strip of 15 m along the banks of rivers, streams, springs and along roads with quick growing species of medium height.
2ag(*)	Create a buffer zone at least 15 m wide around the perimeter of the plantation. This zone should be planted with native species to restore the ecosystem and improve biodiversity.
2ah(**)	Plant and maintain vegetative cover in the drainage canals.
	PEST MANAGEMENT **Control of Nematodes**
2bb	Introduce organic material into plantation soil to promote organisms antagonistic toward pathogenic nematodes.
2be	Use application systems with returnable security packaging (i.e. Surefill).
2bf	Plant and maintain a cover crop to improve the retention of the nematicides and to reduce the risk of water contamination.
2ca(**)	PEST MANAGEMENT
2cb(**)	**Control of Weeds**
	Plant a vegetative cover crop on 70 - 80 % of the floor of the plantation.
2cc(***)	Establish an acceptable threshold for vegetative cover on the floor of the plantation and maintain the maximum acceptable cover.
2ce	Cover plantation soil with minicompost piles that generate organic manure and act as mulch to prevent the growth of weeds.
	Use low volume spraying systems for the application of systemic herbicides.

Table 22 (Cont'd)- Best Available Production Practices

N°	SUMMARY DESCRIPTION
	FERTILIZATION
3a	Design fertilization programs based on soil studies, the climate, and the requirements of the cultivation.
3b	Increase the frequency of applications and reduce the amount of fertilizer per application.
3c	Vary the forms of fertilizer application according to the weather and edafic factors.
3d	Use application techniques that localize fertilizer in the most appropriate locations for plant uptake.
3e(***)	Complement fertilizers with applications of organic biological products and compost.
3f	Apply micronutrients via aerial spraying to complement normal fertilization.
3g	Apply humic acid complemented with micro- and macro-nutrients that can be applied to the leaf and/or the soil.
3j(**)	Plant and maintain cover crops to capture and released the fertilizer slowly.
3k(*)	Establish a buffer zone between areas where fertilizer is applied and the canals.
	FRUIT CARE
	Bagging
4aa	Intercalating bags with and without insecticides in areas with low *Colaspis* pressure, carefully monitoring the farm for insect pests and damage.
4ab	Use a "necktie system" introducing a strip of material impregnated with insecticide inside the bag instead of impregnating the bag itself.
4ac	Use a continuous roll of plastic instead of precut bags (Layflat).
4ad	Use high density polyethylene bags.
	FRUIT CARE
	Propping
4bb	Install overhead aerial support systems.
4be	Use twine made with 20 to 40% recycled resin.
4bf	Use continuous rolls of twine dispensed from a backpack and cut with an appropriate tool.
	HARVEST
5a	Remove the hands from the bunch in the field to avoid the use of cushions.
5c	Deflower the fingers in the field to eliminate *Microlepidoptera* larvae and organic residues in the packing plant.
5d	Pre-wash the fruit by setting up sprinklers along the cable way to lubricate and freshen the fruit during transport.
	PACKING
6a	Use packing material that is recycled and recyclable.
6b	Redesign the tanks to reduce the volume of water used, and recycle the water through the selection tanks.
6c	Purify the water so the water used throughout the packing process can be recycled.
6d	Install filters to treat the effluent water that is contaminated with agro-chemicals.
6e	Certify the wooden pallets.
6g	Use the rejected fruit as a source of organic material for making compost.
6h	Process the stem of the bunch for compost, paper, or other uses.
6I	Redesign maintenance areas so the floors are impermeable and spills of grease and combustibles can be contained.
6k	Use spraying chambers and modify the conventional hydraulic spray nozzles to electrostatic nozzles, considerably reducing the volume of application and avoiding spilling and loss.
6m	Relocate and redesign the warehouses for agro-chemicals and the plastic bags impregnated with insecticides to reduce the risk of environmental contamination and to increase the safety of the workers.

Table 23 - Best Available Labor Management Practices

N°	SUMMARY DESCRIPTION
	HIRING PRACTICES
7ab	Implement a system of bonuses for quality and yield of work.
7ac	Create a bonus system that promotes attendance and prevention of accidents.
7ad	Pay the severance benefit for good workers each six months as a premium for their work.
7ae	Require that all contractors comply with the laws and regulations concerning workers' rights, including those clauses related to the safety guidelines and hygiene.
	FRINGE BENEFITS
7ba	Actively collaborate with local authorities and neighborhood development associations to improve public services in the communities surrounding the plantation.
7bb	Help workers to construct their own homes in the neighboring communities.
7bc	Help workers to construct and operate a transportation company to provide transport services for employees and students.
7bd	Help to construct and maintain a community cultural clubs.
7be	Establish a system of nursery schools so women have the same opportunities as men to work in the plantation.
7bf	Establish a training program for the families of the workers to promote the creation of micro-enterprises that provide services to the plantations and the communities.
7bg	Designate land not used for banana production as space for family gardens for the workers.
7bh	Promote religious activities within the plantation community and in neighboring communities.
7bi	Promote organizations that support women and families.
	LABOR MANAGEMENT PRACTICES
	RISK PREVENTION
7ca	Strengthen the occupational safety unit.
7cb	Fund a preventative medicine unit that includes a company doctor.
7cc	Create a data bank to track occupational accidents.
7cd	Include a labor contractual clause requiring the use of safety equipment.
7ce	Establish an obligatory orientation course for all workers.
7cf	Establish a unified training program and license workers to carry out high risk jobs.
7cg	Institute routine, programmed safety courses for pilots, warehouse employees, and mixing plant operators to improve the operation of the airport facilities.
7ci(*)	Create protection and buffer zones of at least 100 m between the plantation, the packing plant, and employee living quarters.
7cj	Evacuate field workers before aerial spraying and observe re-entry period
7cl	Guide aerial spraying by using a "Flying Flagman" system or with GPS.
7cm	If a GPS system is not available, use mobile globes.
7co	Partially eliminate the use of herbicides and control weeds manually.
7cr	Determine the base range of cholinesterase in each worker who is in contact with clorpyrifos and monitor blood levels every three months.
7ct	Install aerial support systems for propping banana plants.
7cv	Redesign the workplace with ergonomics in mind.
7cw	Relocate and redesign warehouses for agro-chemicals and plastic bags to improve workers' safety and minimize the risk of environmental contamination.

The establishment of a list of BAP, allowed for the calculation of the mean ENPI, SOPI, and ECPI for each of the categories included in the SS. Table 38 shows the results of this procedure and the indices (ENPI, SOPI, and ECPI) for the CPP. This table was included in Appendix C because it was very extensive. These resulting mean values were introduced into the SS to calculate the SPI_{cpp} and SPI_{bab} and the results are reported in the next section.

Table 24 - CPP with Unacceptable Levels of Performance

CPP	ENVIRONMENTAL PERFORMANCE INDEXES (ENPI) EXPERT NUMBER 1	3	4	5	7	8	9	11	12	13	15	Mean	STD. DEV.	STD. ERR.	0.60 T-STU (2)	T-STU CK
1a	0.600	0.270	0.496	0.600	0.413	0.600	0.290	0.200	0.364	0.280	0.416	0.412	0.15	0.04	-4.28	-1.81
1b	0.600	0.420	0.559	0.600	0.515	0.600	0.550	0.480	0.465	0.600	0.451	0.531	0.07	0.02	-3.37	-1.81
2a	0.600	0.200	0.515	0.600	0.430	0.600	0.200	0.280	0.209	0.200	NO	0.383	0.18	0.06	-3.74	-1.83
2b	0.600	0.220	0.463	0.600	0.361	0.600	0.240	0.100	0.309	0.200	0.138	0.348	0.19	0.06	-4.39	-1.81
2c	0.600	0.200	0.460	0.600	0.363	0.600	0.200	0.800	0.314	0.200	0.163	0.409	0.22	0.07	-2.93	-1.81
3	0.600	0.265	0.391	0.600	0.584	0.600	0.300	0.600	0.325	0.200	0.258	0.429	0.17	0.05	-3.39	-1.81
4a	0.600	0.240	0.210	0.600	0.487	0.600	0.540	0.440	0.150	0.200	0.227	0.390	0.18	0.06	-3.76	-1.81
4b	0.600	0.275	0.550	0.600	0.544	NO	0.460	0.440	0.150	0.400	0.380	0.440	0.15	0.05	-3.47	-1.83
6	0.600	0.545	0.522	0.600	0.551	0.600	0.400	0.600	0.230	0.600	NO	0.525	0.12	0.04	-1.96	-1.83
8	NO	0.300	NO	0.320	0.600	0.220	0.420	0.320	0.275	0.500	NO	0.369	0.13	0.04	-5.72	-1.94

4.9 Sustainable Performance Indices (SPI)

Using the results reported in the previous sections, the SS hierarchical structure was programmed into ECPro and the corresponding SPI calculated. One individual program was created for each expert because the intensities were different. The SPI values for the CPP and BAP for each of the experts were introduced into the experimental design matrix (Table 25 in section 4.10). The ten experts fill the rows of the matrix. The columns contain the SPIcpp for each expert, the second column contains the SPIbap for each of the corresponding experts, and the third column holds the value representing an acceptable level for performance index (0.6). The completion of the experimental design matrix makes it possible to test the hypothesis. The next and final section of this chapter presents the results of the hypothesis testing.

4.10 Hypothesis Testing

The objective of this dissertation, as stated in its title, was to design a systems method for evaluating the sustainability of ag-production. Banana production for the export market in Costa Rica was chosen to test the method. Correspondingly, the following questions were asked:

- Can a suitable quantitative measuring method be devised to evaluate the sustainable performance of agricultural production practices?
- Can appropriate quantitative ordinal sustainability indices be developed to evaluate banana production processes?

To answer these questions, a method was designed that contemplated a mathematical procedure to derive indices to test sustainable performance. The adequacy of the proposed method was to be tested by answering the following questions:

- Is the current banana production in Costa Rica sustainable?
- If not, what changes can be implemented to improve sustainability?

Accordingly, the proposed hypotheses were the following:

Hypothesis A

H_0: The CPP are environmentally, socially and economically acceptable.

H_1: The CPP do not environmentally, socially and economically acceptable.

Hypothesis B

H_0: The BAP are environmentally, socially and economically acceptable.

H_1: The BAP are not environmentally, socially and economically acceptable.

The experimental design used for this dissertation was a two-way classification matrix using three treatments and ten repetitions. The treatments were conventional production practices, best available practices and minimal acceptable sustainable practices. The three treatments were organized in the columns of the matrix. The repetitions were the indices derived from the opinions given by the ten experts. Table 25 presents the experimental design matrix with the values resulting from the calculation of the SPI for CPP and BAP for each expert. The scale used to judge sustainable performance, stated that acceptable performance requires an SPI equal or better than 0.6. Indices below 0.6 were not acceptable. For this reason the third column of the matrix was filled by an index value of 0.6.

Table 25 - Experimental Design Matrix

PE	SPIcpp	SPIbap	Acceptable Index Value
1	0.613	0.646	0.600
3	0.458	0.526	0.600
4	0.567	0.646	0.600
5	0.604	0.673	0.600
7	0.544	0.543	0.600
8	0.611	0.673	0.600
9	0.523	0.673	0.600
11	0.555	0.641	0.600
12	0.486	0.662	0.600
13	0.521	0.680	0.600

Two levels of testing were proposed. In the first level, a one-way analysis of variance (ANOVA) procedure was proposed to test if the two sets of data were samples of the same population and if the mean of those samples was statistically equal to 0.600. In mathematical terms, the hypothesis to be tested was expressed as follows:

H_O: $\mu_{cpp} = \mu_{bac} = 0.600$

H_1: $\mu_{cpp} \neq \mu_{bac} \neq 0.600$

A significance level of 0.05 was chosen for this analysis.

Table 26 shows the descriptive statistic and table 27 shows the results of the ANOVA. From the results, it is evident that for a significance level of 0.05 the null hypothesis is rejected. In order not to reject the null hypothesis, it would be necessary to use a significance level of 0.001. Figure 4.26 was given as part of the results using MINITAB which was very illustrative. The figure represents theoretical acceptance range of values at a confidence level of 95% and using a pooled standard deviation for the three columns being tested. The SPIcpp data set apparently had a minimal area of its acceptable range of values that overlaps the "acceptable index value" theoretical acceptance range of values. The SPIbap had a larger area of overlap. This meant that the SPIbap were closer to 0.6 than the SPIcpp.

Table 26 - Descriptive statistics of the two samples

NAME	N	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
SPIcpp	10	.548	.0528	.458	.613
SPIbap	10	.636	.0555	.526	.680
Acceptable	10	.600	.0	.600	.600
Gran Mean	30	.595			

Table 27 - Results from the ANOVA Using MINITAB

SOURCE	SS	D. F.	MEAN SQUARE	F RATIO	PROB.
Between	0.3921	2	.01960	10.04	0.001
Within	0.5275	27	.00195		
Total	0.09195	29			

```
              -+---------+---------+---------+-----
SPIcpp        (------*------)
SPIbap                              (------*------)
Acceptable               (------*------)
              -+---------+---------+---------+-----
             0.520     0.560     0.600     0.640
```

Figure 11 - Individual 95% Confidence Intervals for Mean Based on Pooled Standard Deviations

The rejection of the null hypothesis means that at least one of the data sets is not a sample of the same population. It was necessary to do a second level of analysis to identify which set or sets of data were not equal. For this analysis, one-way ANOVA was performed comparing SPI_{cpp} with SPI_{bap} (Case 1), and then comparing SPI_{bap} with 0.600 (Case 2). The procedure was repeated comparing SPI_{cpp} with 0.600 (Case 3). The hypothesis to be tested is expressed in mathematical terms as follows:

Case 1

H_0: $\mu_{cpp} = \mu_{bap}$

H_1: $\mu_{cpp} \neq \mu_{bap}$

Case 2

H_0: μ_{bac} = Acceptable = 0.600

H_1: $\mu_{bac} \neq 0.600$

Case 3

H_0: μ_{cpp} = Acceptable = 0.600

H_1: $\mu_{cpp} \neq 0.600$

The results are shown in Tables 28, 29, and 30. According to these results, in the first and third cases the null hypothesis was rejected at a significance level of 0.05. In the second case the null hypothesis was not rejected. The significance of these findings is that there is a considerable difference between SPI_{cpp} and SPI_{bap}, that SPI_{bap} is statistically equal to the acceptable level of performance, and that SPI_{cpp} is at an unacceptable level of performance. Therefore, the answer to the question -- is the current banana production in Costa Rica sustainable? is no, assuming that the CPP is representative of the industry. Since SPI_{bap} is equivalent to 0.60 (acceptable sustainable performance), the answer to the question -- what changes can be implemented to improve sustainability? is given by the list of activities in Table 4.12 and 4.13.

Table 28 - Results of Comparison of SPI_{cpp} with SPI_{bap} Using MICROSTAT

Group	Mean	n
1	.548	10
2	.636	10
Grand Mean	.592	

SOURCE	SUM OF THE SQUARES (SS)	DEGREES OF FREEDOM (DF)	MEAN SQUARE (MS)	F RATIO	PROB.
Between	.039	1	.039	13.244	.001876
Within	.053	18	.0029303		
Total	.092	29			

Table 29 - Results of Comparison of SPI_{bap} to 0.600 Using MICROSTAT

Group	Mean	n
2	.636	10
3	.600	10
Grand Mean	.618	

SOURCE	SUM OF THE SQUARES (SS)	DEGREES OF FREEDOM (DF)	MEAN SQUARE (MS)	F RATIO	PROB.
Between	.0065885	1	.0065885	4.283	0.053
Within	.028	18	.0015384		
Total	.034	29			

Table 30 - Results of Comparison of SPI_{bap} to 0.600 Using MICROSTAT

Group	Mean	n
1	.548	10
3	.600	10
Grand Mean	.574	

SOURCE	SUM OF THE SQUARES (SS)	DEGREES OF FREEDOM (DF)	MEAN SQUARE (MS)	F RATIO	PROB.
Between	.013	1	.013	9.639	.006116
Within	.025	18	.0013919		
Total	.038	19			

As stated in section 4.2, the composition of the PE was carefully balanced including half of its members as being directly involved with production of bananas, and the other half indirectly involved. To justify the selection process, it was important to identify if there were differences in the sustainable performance indices derived from the opinion of each segment. A one-way ANOVA was performed comparing the indices of one segment against the other. The hypothesis for this test is as follows:

H_0: $\mu_{prod.} = \mu_{non\text{-}prod.}$

H_1: $\mu_{prod.} \neq \mu_{non\text{-}prod.}$

The results of this analysis are shown on Tables 31, 32 and 33. According to the results of the test, the null hypothesis was rejected. The two sets of data are different at a significant level of 0.05. However, it is important to note that at a significance level of 0.0238, the null hypothesis would not be rejected. This means that the normal distribution curves for both sets have almost no overlap. Figure 12 illustrates this information graphically.

Table 31 - Tabulation of SPI by Segment of PE

PE PROD.	Mean SPI_{prod}	PE NON-PROD	Mean $SPI_{non\text{-}prod}$
1	0.6295	3	0.4920
4	0.6065	7	0.5435
5	0.6385	9	0.5980
8	0.6420	12	0.5740
11	0.5980	13	0.6005

Table 32 - Descriptive Statistics of the Two Segments

NAME	n	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
SPIprod	5	.6229	.0196	.5980	.6420
SPInon-prod	5	.5616	.0452	.4920	.6005
Gran Mean	10	.592			

Table 33 - Results of Comparison of SPI_{bap} to 0.600 Using MICROSTAT

SOURCE	SS	DF	MS	F RATIO	PROB.
Between	.0093942	1	.0093942	7.744	.00238
Within	.0097044	8	.0012131		
Total	.019	9			

```
              -+---------+---------+---------+-----
SPIprod                          (--------*--------)

SPInon-prod (--------*--------)

              -+---------+---------+---------+-----
              0.520     0.560     0.600     0.640
```

Figure 12 - Individual 95% Confidence Intervals for Mean Based on Pooled Standard Deviations

By observing the descriptive statistics, it was evident that the experts in the segment that were not directly involved in production, had a wider range of opinions (.1085 point spread versus .44 and a standard deviation of 0.0452 versus 0.0196), and that they were more likely to give lower ratings. The explanation stems from the fact that the non-production segment of the experts was involved in a wider range of activities and was less homogeneous than the segment that is directly involved in production. Furthermore, the segment directly involved in production could not afford the luxury of being pessimistic about banana production because it was their source of financial sustenance.

The previous sections of this chapter have described and illustrated the results in tables and figures. Remarks were made pointing out the importance of the results and explaining them. In the next chapter, the author has the charge of making sense of the results, drawing conclusions and offering recommendations.

Chapter V

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The purpose of this chapter is to interpret the results presented in the previous chapter in search of an answer to the researchable question object of this dissertation. With the intention of ordering this procedure, section 5.2 of this chapter revisits the problem statements presented in Chapter One. Section 5.3 examines the researchable question and dissects it into its components. Section 5.4 – Findings and Conclusion - submits the answers to the researchable questions. Section 5.5 presents recommendations, and section 5.5 presents the concluding statements

5.2 Problem Statement

The facts presented in Chapter One and Chapter Two of this document sustain the following problem statements:

- All agricultural production practices introduce disturbances in the ecosystem and have a resulting impact on the environment, society, and the economy. A production practice is sustainable when the negative impact on society and the environment are minimized, and the benefits (present and future) to society and the economy are maximized.
- The environment has the resiliency to assimilate a moderate amount of disturbance. Conventional production practices (CPP) for growing bananas introduce a massive disturbance in the ecosystem and their impact may be beyond the limits of the environment to absorb the insult. Therefore, banana CPP may not be performing in an environmentally sustainable manner.

- Banana CPP brings many benefits to the workers and their families, neighboring communities and the nation, but they also may be directly or indirectly responsible for part of the serious social problems evidenced in the banana production region. Furthermore, banana exports require a large national resource investment that generates a substantial economic benefit to few transnational firms, national firms, and individuals. Conventional development paradigms rely on the trickle down effect for benefits to reach all the stakeholders. The present structure of ownership and marketing of bananas may provoke a deficient distribution of benefits. Therefore, banana CPP may not be performing in a socially sustainable way.
- The present banana market conditions may be generating insufficient economic benefits to Costa Rica that may not compensate the negative impact on the environment and society. Therefore, CPP may not be performing in an economically sustainable pattern.
- Consequently, the banana CPP used in Costa Rica may not have an acceptable sustainable performance level and it may be necessary to identify and introduce the better practices (BAP) to improve the net benefit.
- BAP also have negative impacts on the environment, the society and the economy. Therefore, BAP may not achieve an acceptable level of sustainable performance.
- If both CPP and BAP are not performing to a desired level of sustainability, then it may be advisable to abandon banana production. However, abandoning banana production may have a catastrophic impact on the environment, society and the economy of Costa Rica. Furthermore, alternatives to banana production may perform in a less sustainable manner.

These problem statements introduce a sequence of uncertainties that are considerably important to decipher for the future of countries that have a large dependency on cash crops for their current well being. To clarify these uncertainties, it is critical to collect, appraise and organize information, under a systematic method. A systematic method allows the analyst to clarify the questions latent in the problem statements, to identify components of the system that require immediate change, to appraise alternative solutions, and to recognize areas that demand further research and development. The end-result is an appropriate set of recommendations that aid the decision makers in taking sustainable actions. The objective of this dissertation was to propose and test a systematic method of analysis for evaluating the sustainable performance of agricultural production practices. It uses banana production for the world market to test the adequacy of the method. The researcher recognizes that there are not enough "hard facts" available at this time and relies on the opinion of a panel of experts.

The first task was to outline a working definition of sustainable banana production. The following definition was adopted after an extensive review of the literature and consultations with several of the members of the PE,

> *"The sustainable production of world-class bananas is a broad spectrum of agro-cultural practices that includes the efficient and rational use of natural resources and the agroecosystem. It seeks to ensure long-range production, productivity, and profitability by maintaining and improving the resource base and preventing environmental degradation. It distributes costs and benefits fairly and equitably, and respects community values and principles, all with the objective of satisfying society's present and future needs, and improving the quality of life of the community". (Synopsis of concepts expressed by del Camino and Muller, 1993 and Tabora, 1991, and CSA, 1992)*[16]

The challenge was to construct a model of world-class banana production in Costa Rica that adequately fits this definition and answers the questions inferred in the problem statements. After the model was delimited, the challenge was to devise a suitable quantitative measuring method to evaluate and relate the effects of production practices on the environment, society and the economy. This implied the development of a quantitative method of calculating sustainability performance indices to evaluate production processes. The resulting indices, to be judged appropriately, had to answer the questions of the problem statement with a reasonable degree of confidence and replicability for most agricultural practices.

5.3 Researchable Questions

The question object of this dissertation was - Is it possible to attain a sustainable production system of world-class bananas by modifying the conventional production technology presently used in Costa Rica without significantly changing the market component? Because of its complexity, It was prudent to dissect this question into its components.

1. What are the important criteria that must be met in order to perform in a sustainable manner?
2. What are the conventional banana production practices (CPP) in Costa Rica?
3. Are the CPP performing in an environmentally, socially and economically acceptable manner?
4. Are there best available practices (BAP) that have a better environmental, social and/or economical sustainable performance?
5. Should banana production for the export market be abandoned?
6. What areas should be further researched and developed to improve sustainable performance?

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[16] Defined by Hernández, C. 1996. Guácimo, Limón: Escuela de Agricultura de la Región Tropical Húmeda. Edited by: Rincón H., Fallas, C. and Alfaro, M., and translated to English by Judy, W.

7. Is it necessary to significantly change the market component of the system in order to improve the sustainable performance of banana production for the export market?

8. Was the analytical method proposed appropriate to answer the previous questions?

5.4 Findings and Conclusions

This section will address each of the eight questions proposed in the previous section by interpreting the information presented in Chapter IV.

5.4.1 What are the important criteria that must be met in order to perform in a sustainable manner?

There was unanimous agreement among the members of the PE that the criteria for sustainable performance contain three major components: environmental, social and economic criteria. Furthermore, there was general conformity among the experts that these components could be subdivided into criteria and sub-criteria forming a pyramidal hierarchical structure with different levels of detail. Figures 15 through 36, are a product of review and consensus by the experts. No individual objections were presented to any of the criteria or sub-criteria presented in the figures. Therefore, it can be concluded that the criterion variables used in this research, and presented in Figures 15 through 36, represent reasonably the important criteria that must be considered to evaluate agricultural production activity, and to judge them with respect to their degree of sustainable performance.

5.4.2 What are the conventional banana production practices (CPP) in Costa Rica?

After the interview process, it became evident that few banana production companies in Costa Rica have exactly the same production practices. Different environmental conditions among areas of production require each plantation to customize its technological package. Furthermore, edafic differences within plantations require adjustments and customized procedures for each section of the plantation. Financial constrains limit a large number of producers in adopting some well-recognized best available practices. These differences contribute to the great disparity in level of sustainable performance among banana plantations in Costa Rica.

Table 35 in Appendix B, contains a base line definition of CPP used to compare and rank the alternative production practices. It is a compromised definition and none of the experts agree with every stipulation. Therefore, this description of CPP cannot be generalized and used to characterize the standard practices of the industry because they do not exist. Some plantations have a technological package that is similar to the one described in this document, some apply more advanced practices and some have a less sophisticated package.

For this reason, the method applied in this dissertation is not appropriate to determine the level of sustainable performance of the entire banana growing industry of Costa Rica. It is only appropriate to rate the sustainable performance of individual plantations.

5.4.3 Are the CPP performing in an environmentally, socially and economically acceptable manner?

The CPP, as described in the base line definition used in this dissertation, were rated holistically below the acceptable sustainable performance level of 0.6. The mean SPIcpp value awarded was 0.548, which corresponds to a descriptive rating that is situated between moderately unacceptable (0.4) and acceptable performance levels. Even the lowest value given by the experts places the CPP within this descriptive rating level. It is also evident that even the most optimistic of the experts did not rate the CPP much above acceptable.

If the indices are examined before aggregation, the CPP failed the environmental criteria (mean ENPI = 0.435), but received an acceptable rating in the social criteria (mean SOPI = 0.631). Furthermore, it is significant that there is unanimous consensus that if Costa Rica decides to abandon banana production for the export market, there would be a highly negative effect (mean SOPI = 0.194) on the workers, their families, and the local communities in which they live.

At the present time, not all banana plantations in Costa Rica are economically sustainable. An important group of farms are under the management of the banks because they were not able to meet their financial obligations (ANAPROBAN, 1995). According to the experts, the majority of the farms are breaking even or have low profits. Most producers have adopted strategies to contain costs and to survive until there are better market conditions.

5.4.4 Are there best available practices (BAP) that have a better environmental, social and/or economical sustainable performance?

Table 22 and 23 contain an extensive list of best available practices that if applied improve considerably the sustainable performance of the CPP as they are described in this document. Many of these BAP are already being applied by a large number of farms. All of the BAP in the list are successfully being applied in at least one farm.

A considerable group of BAP, contributes favorably to the environmental performance of more than one category of activities. Evidently the creation of buffer zones, the establishment of ground covers and the addition of organic matter to the soil of the plantation, are practices that significantly decrease the negative impacts of banana production on the environment. All three categories contribute to the conservation and restoration of biodiversity. However, it is crucial to recognize that increasing biodiversity includes the addition of organisms that are health threatening to the workers, such as snakes and insects. It is also important to note that there are more accidents caused by cuts and bruises than there are due to accidents with agrochemicals. Therefore, the implementation of BAP requires considerable planning and modifications of safety procedures.

Notwithstanding, the relatively acceptable social ratings given by the experts to the CPP, there is a large list of activities that would enhance the quality of life of the workers, their family and the local community where they live.

It is noteworthy that many of the BAP included in the list are related to risk prevention.

Most of the BAP have an important impact on the economic sustainability of the system. For this reason, the mean SPIbap rating given by the experts drops to a level close to 0.6. As stated before, many of the plantations have difficulty implementing these practices because they are very close to the break even point and have adopted strategies to reduce costs until there are better market conditions. However, many plantations that have adopted some of the BAP manifest that the increment in costs is temporary, that costs tend to return to the original level and in many cases they tend to decrease after the initial phase. For this reason, growers need to implement the recommended BAP on a gradual manner. Growers need to choose from the list of BAP those which best fit their operational conditions, and those that make the largest positive impact. The implementation of too many BAP in too short a time can lead to serious economic and agronomic problems.

5.4.5 Should banana production for the export market be abandoned?

Judging from the results, banana conventional production practices, as defined in this dissertation, are at worst moderately unacceptable, and there are a large number of best available practices that make it possible to improve. Furthermore, there is consensus among the experts that to abandon banana production would cause a social catastrophe suffered primarily by the workers, their families and the local communities. If Costa Rica abandons banana production for the export market, there still would be a market demand and the transnational companies would probably transfer their operations to other countries with lower environmental and social requirements. In conclusion, the answer to this question is a definite and emphatic no.

5.4.6. What areas should be further researched and developed to improve sustainable performance?

Since resources are limited, it is important to use the intensities assigned by the PE to identify the areas where the allocation of resources has the largest impact on the environment and society. The intensities given by the experts to the three principal components of sustainability – environmental, social and economic – were approximately equal. Within the environmental component, the field activities predominated with 64% of the weight. Of the field activities, pest management received the highest weight (39%), followed by general practices (30%). There was no doubt in identifying the control of black *Sigatoka* as the most impacting practice on the environment.

Within the context of the previous paragraph, it is important to make reference to Table 20. This table presents a list of APP rejected because they require further research. This list includes activities related to biological pest management. Research emphasis should be given to these activities because their impact on the environment and costs is critical and decisive for improving sustainable performance of banana production.

Within the social component of the system, hiring practices was given the highest priority, closely followed by risk prevention practices. Since the banana workers of Costa Rica are the highest paid agricultural workers in the country and the highest paid banana workers in the region, improvement in this area is limited without out-pricing Costa Rica's bananas in the world market. In contrast, risk prevention is of utmost importance to preserve the quality of the workers and their ability to maintain their jobs and sustain their families. Investment in risk prevention reduces cost to the plantation owner by minimizing unproductive time and safeguarding the training investment made in each worker. It is critical to recognize that good health is a prerequisite for good quality of life, and good quality of life is a crucial objective of sustainable development.

Examining the economic component (Figure 9), the largest effect is manifested in the inputs (49.7%). The highest cost input is packaging (40.5% of the inputs). It is interesting that the experts did not provide any significant cost reduction best available practice for packaging. This indicates that the conventional practice is the best available for the quality standards demanded by the market. It also indicates that there is a great need for further research and development in this area.

The fungicides (15.5% of the inputs) are the second most important item of the inputs and black *Sigatoka* control contributes greatly to this item. Pest management and *Sigatoka* were already identified as areas that are critical. Economic considerations re-enforce the necessity for further research and development in black *Sigatoka* control.

The second most important item in the economic component is the labor component (31.8%). Salaries and Benefits constitute the majority of cost. Risk prevention is a hidden cost component included in this item that was already identified as a critical area for research and development.

4.5.7 Is it necessary to significantly change the market component of the system in order to improve the sustainable performance of banana production for the export market?

The results demonstrate that it is possible to make a significant difference in the sustainable performance of banana production without changing the market component of the system. It is also true that the burden for change is being placed on the producer and not on the consumer. As stated before, many producers are close to the break-even point due to low market prices and are hesitant to accept changes unless costs are maintained constant or are lowered.

Price recognition for producers adopting better production practices is a powerful catalyst for the prompt adoption of BAP. A higher price for products that do not physically evidence quality differences is difficult to achieve under the present market structure. However, in a buyer's market, where there is excess production, marketing companies are open to use product differentiation methods to improve their market share. To recognize products produced under BAP, the consumer needs a reliable and well-recognized labeling system. There are many organizations and methods for awarding green labels and a few for issuing good trade practice labels. Chiquita has chosen to use the ECO-OK label as a means of improving their image and as a mechanism of differentiating their bananas from those of the competition. Companies like Del Monte have chosen to pursue certification under ISO 14000 because it is an international organization that is recognized in the United States and Europe. The method tested in this dissertation can be integrated into the ISO 14000 and the ECO-OK certification methodology.

5.4.8 Was the analytical method proposed appropriate to answer the previous questions?

The systematic method of analysis proposed provided significant results, allowing the researcher to answer the questions with a reasonable level of confidence. The results permitted statistical synthesis, analysis and hypothesis testing. There was no indication that this method had any problems of applicability to other agricultural activities.

The steps necessary to complete the analysis are well defined and are easily replicated. However, the method, as used in this research, is highly sensitive to the composition of the Panel of Experts. It is critical to have a balanced multidisciplinary panel that includes experts working in the full range of task related to the agricultural activity in question. Otherwise, the results may be skewed and not replicable.

Using focus interviews instead of the Delphi method for the first interview may enhance the performance of the Panel of Experts. The focus interview allows for the interchange of ideas and the arrival of consensus opinions. The disadvantage is that the researcher cannot be committed to maintaining confidentiality. This would limit the participation of some experts whose job security may be threatened by their opinions. In this case an important segment of participants may be limited and the results may be skewed. It is important to keep the second interview on an individual basis because the focus interview limits the application of statistical methods for synthesis, analysis and hypothesis testing.

As stated in section 5.4.3, the CPP described for this research are not necessarily representative of the banana growing industry. For this reason, the method, as applied in this dissertation, is not appropriate to determine the level of sustainable performance of the entire banana growing industry of Costa Rica. It is only appropriate to rate the sustainable performance of individual plantation. As such, it is an appropriate method for awarding market labels to individual plantations.

In order to emit an accurate generalized judgment on the industry, it is necessary to evaluate every plantation and aggregate the results. This is a monumental undertaking that requires the consensus of all the owners since property rights are well defined and respected in Costa Rica. A viable alternative, but less accurate, is to choose at random a significant number of plantations, apply the method and aggregate the results. This procedure requires institutional sponsorship and assurance of confidentiality. Otherwise the individual researcher will probably encounter resistance by the owners of the plantation since the information gathered may reveal trade secrets or may be used to discredit their operation.

One of the members of the PE criticized and questioned the method used. His opinion is noteworthy and should be recorded. His convictions prevented him from assigning weights to the three fundamental elements of sustainability – environmental, social and economic. To him each element deserves 100% and if one fails all fail. In his view, sustainability has to be looked at as an organism, which has several vital organs that allow it to survive. If one vital organ fails, the organism dies even if the other organs are perfectly healthy.

Assuming that the organism's analogy is valid, homeostasis maintains the equilibrium regulating and compensating the different interactions among the other organs, before total failure occurs in one organ. This permits the organism to regenerate or repair the organ that is malfunctioning. From the results obtained in this research, evidently the situation has not reached fatalistic consequences. It is still possible to compensate the shortcomings of one component with the benefits of the others. Furthermore, there is a long list of BAP that can be used to improve the shortcomings of the present system. Thus the separation of sustainability into its three basic components (environmental, social and economic) and the assignment of weights or intensities is justifiable using the organism's analogy.

In conclusion, the overall results of the method proposed were satisfactory. The method proved to be useful for gathering, organizing and analyzing large quantities of complex subjective and objective data. It is sufficiently sensitive to allow the user to draw conclusions. The method can be applied to other agricultural production activities and can be replicated.

Notwithstanding its overall success, it proved to have shortcomings that must be adjusted for better results. These shortcomings will be addressed in the following section – Recommendations. Since the proposed method has merits and may be used for prospective applications, the name Sustainability Performance Evaluation Method and the acronym SPEM will be used for future reference.

5.5 Recommendations

The overall success of the application of SPEM for rating agricultural production practices according to their sustainable performance index and the opportunities available for future use, motivates the researcher to make the following recommendations:

- SPEM, as applied in this research, was dependent on subjective evaluation data for the environmental and social components. SPEM easily allows the incorporation of "hard facts" as they become available. Furthermore, SPEM is flexible permitting the inclusion of more levels of detail. To validate the results of this dissertation, it is recommendable to use the cause and effect diagrams (Figure 15 through 36) to identify future studies. Preferably, these investigations should be specifically framed within the environmental and social components to derive data based on objective facts.
- It is advisable to identify an organization that represents all the banana industry's stakeholders to develop the full potential of SPEM. The Environmental Banana Commission is the banana industry's forum for the discussion of environmental issues. The representatives of all the banana industry's stakeholders integrate CAB. Because of the intimate relationship that the environment has with the social and economic elements of the system, CAB can easily be amplified to include them into its platform. In its modified form, CAB can become an effective channel for attaining excellence in sustainable performance and SPEM a useful tool to evaluate change.
- It was not possible to successfully evaluate the overall sustainable performance of the banana growing industry because the CPP could not be defined to the overall satisfaction of the experts. Since this evaluation may be useful for planning purposes, it is recommendable that a trade-organization assumes the challenge of gathering the necessary information.

The CAB has an in-place system of inspection that audits the growers' compliance to the 1993 environmental commitments made by the industry to the people and government of Costa Rica. The SPEM can easily be incorporated into this system of inspections as an evaluation tool. The aggregated results of CAB's evaluations using SPEM can provide a reliable appraisal of the environmental performance of the industry.

- There is a need to revitalize the combined efforts of the industry to attain excellence in sustainable performance. It is recommendable that the industry, through CAB, adopts the list of BAP compiled in this dissertation as their goal, assuming a new challenge and bolstering its commitment to sustainable development.
- The panel of experts, through the definition of weights or intensities, identified the areas that have the largest effect on sustainable performance. This is useful information that should be considered by the industry to define their research and development programs. This is especially true of CORBANA's research and development department, which provides information to all the growers of Costa Rica.
- SPEM has the potential of becoming a useful tool to evaluate the sustainable performance of individual farms. It can be applied by the owners to rate their individual operation with respect to other plantations, and to define areas that need improvement. The banana industry, through CAB, should sponsor a series of workshops to analyze each of the elements of sustainability and validate SPEM. If as a result of these workshops SPEM is validated, CAB should disseminate it as a tool for planning the investments of the industry and the individual growers.
- SPEM should be scrutinized by certification organizations, such as the Rainforest Alliance and the AMBIO foundation, to assign ratings and to determine plantation that merit a sustainable performance label. Growers, through labels, need a reliable and inexpensive method of gathering and relaying information to the consumers that differentiate their product over those of the competition. SPEM provides a mechanism for certification of growers' claims. On the other end, consumers need to feel confident that the information provided by the label is correct and verifiable. Information processed by SPEM can be replicated and verified by auditors. Most available market labels recognize specific elements of sustainability, but no major market label recognizes a combined sustainability rating. SPEM offers a mechanism for certification organizations to amplify labeling scope.
- The banana industry of Costa Rica has been singled-out by European environmental groups and criticized for the negative impacts that it supposedly has on society and the environment. The banana industry should conduct a comparative analysis of the bananas, coffee, cattle, sugar cane, citrus, heart of palm and pineapple industries' to determine overall sustainable performance. It should also include a comparative study between bananas and some of the crops produced in the European

countries. These studies should include the analysis of the banana industry of other producing countries, especially those that enjoy trade privileges from the European Union. The results of these studies can verify the banana industry's comparative and relative effects on the environment and society, and guide Costa Rican producers into a new decade of prosperity.

5.6 Concluding Remarks

Banana production for the export market is a very important activity for Costa Rica's social and economic stability. Conventional banana production practices, as defined in this dissertation, have a moderately unacceptable sustainable performance level. New and better "eco-safe" production technologies are needed that are environmentally and socially friendly, as well as cost effective.

Large-scale production of "eco-safe" bananas is difficult and complex under the ecological conditions found in the humid tropics. The future is in the application of clean technologies, which use natural resources and processes rationally, and decrease producers' dependency on agrochemicals. Eco-development compatible technologies and biotechnology will play important roles in this new sustainable banana production paradigm.

There are evidences that the adoption of better production practices may bring positive long-term economic effects, which counter-act the investments that are needed. At this time there are not enough conclusive evidences that this is the case. Furthermore, not all the appropriate clean technologies proposed by the panel of experts have been tested on a large scale. Consequently, growers have reservations in adopting them because of the risk involved. Validation of best practices at the pilot project level is urgently needed before industrial wide use can be recommended.

Individual growers should carefully analyze the best available practices. The objective is to identify which of these practices best fits individual conditions and which will contribute with the largest impact to improve sustainability. Gradual implementation of the best fitting and available practices is advocated in order to minimize the initial shock and allow for a gentle adjustment of the system.

A considerable sector of the banana industry is economically stressed, and funds for research and development are not readily available. The introduction of fresh sources of funds is necessary. The industry's troubles are partially adjudicated to the excessive reliance on agrochemicals and the developed pest resistance to them. The agrochemical companies are profiting from this dependency, and have the funds required for developing clean technologies. No one expects these companies to invest in changes that decrease their profits. However, new concepts and innovative technologies, that permit a particular agrochemical company to develop a market edge over its competitors, provide a powerful incentive for investment. Research institutions such as CORBANA and the universities must look towards multilateral developing agencies for funds for research and development to address areas that are of no interest to the agrochemical companies.

The European Union countries are projecting stricter barriers on the purchase of products that are not produced with eco-safe technologies. A small but vociferous group of consumers has demonstrated a willingness to purchase and pay for "organic products". However, there is no indication that political barriers and license requirements, which frustrate independent marketing effort to introduce eco-safe bananas in Europe, are going to change. On the other hand, banana-marketing firms are not willing to introduce eco-safe bananas voluntarily as a choice to the consumer because there are not enough market incentives. Therefore, Costa Rica's growers must form strategic alliances to educate the consumers and differentiate eco-safe bananas from others. The consumer must have a clear understanding that by purchasing an eco-safe banana he or she is contributing not only to the conservation of the environment, but also to the improvement of the workers' and the communities' quality of life.

Transnational companies play a very important roll in the banana business and should be kept as an significant part of the banana industry in Costa Rica. Nevertheless, Costa Rica's authorities should have effective control mechanism and alternate marketing options to maintain a balance between the economic interest of transnational companies and the well being of the country. It should use international conventions, and bilateral and multilateral trade agreements to ensure a place in the market for Costa Rica's fresh bananas.

Costa Rica should also promote added value processing of the fresh fruit. There is a great potential for eco-safe bananas in the baby food business that should be optimized. Other banana products have been extensively researched such as starch, flower, alcohol, vinegar, syrup, juice, and snacks. The high level of education of Costa Rica's labor force is a strength in the establishment of high technological processes. The government should motivate research and development of new and appropriate value-added technologies, and aid projects, which pursue this line of business. Authorities should re-direct revenue collected through the environmental tax on banana exports to its original destination – research and development of human and environmental health.

The Government of Costa Rica should provide incentives for crop diversification and the elimination of unproductive farms. It should also check the concentration of land in few hands. Cooperative farms in banana production have not been successful. Therefore, new and innovative schemes should be introduced to increase the opportunities of small farmers to make a decent living, using their land wisely. The forestry sector has taken the lead with the carbon exchange and wood futures programs. The banana sector should follow their example.

There is a place for banana production in the future of Costa Rica, provided that decision makers act wisely to make appropriate and timely adjustments. Properly digested information is a key factor in making wise decisions. This dissertation contributes with a method – SPEM – to systematically collect, synthesize and analyze large quantities of complex data. It is capable of ranking alternative solutions using sustainable performance indices. It is also capable of monitoring the effects of change to provide feedback information. SPEM is a useful decision making tool that can contribute positively in the sustained development of a new era of prosperity for Costa Rica's banana industry.

APPENDICES

APPENDIX A

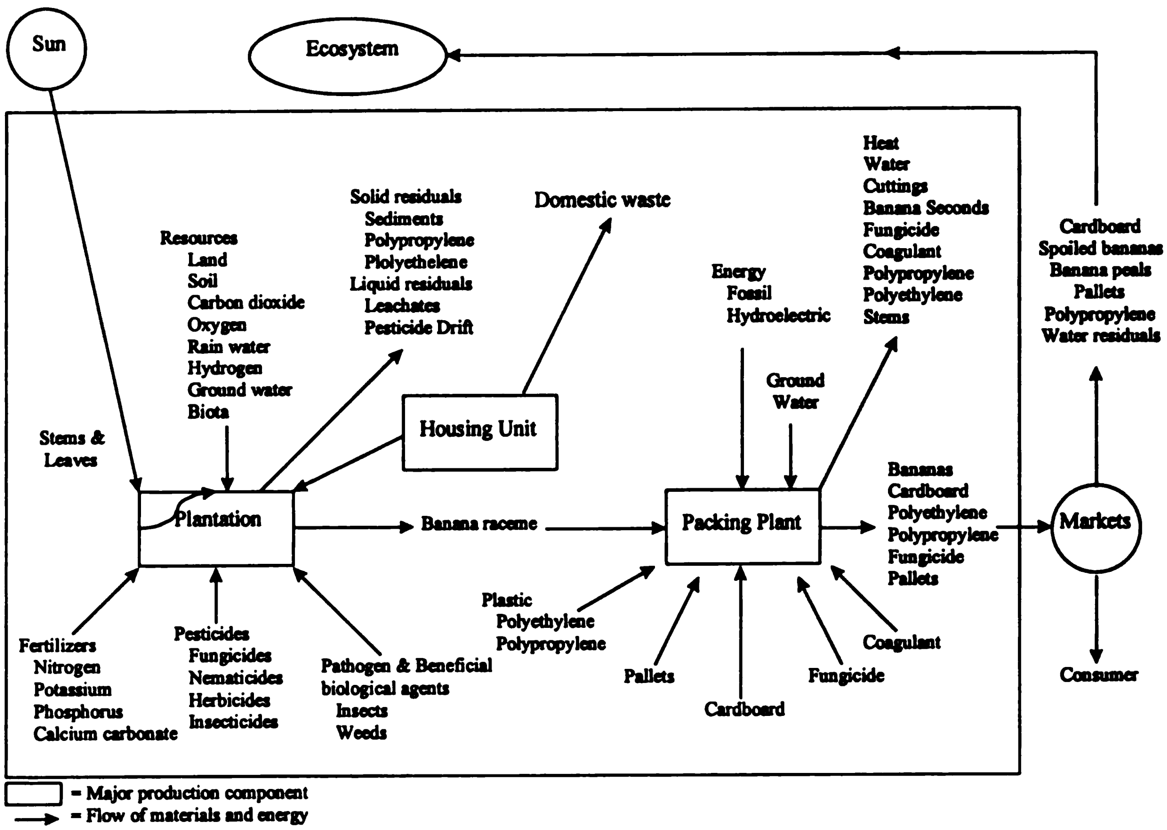

Figure 13 - Macro Level Banana Production Model

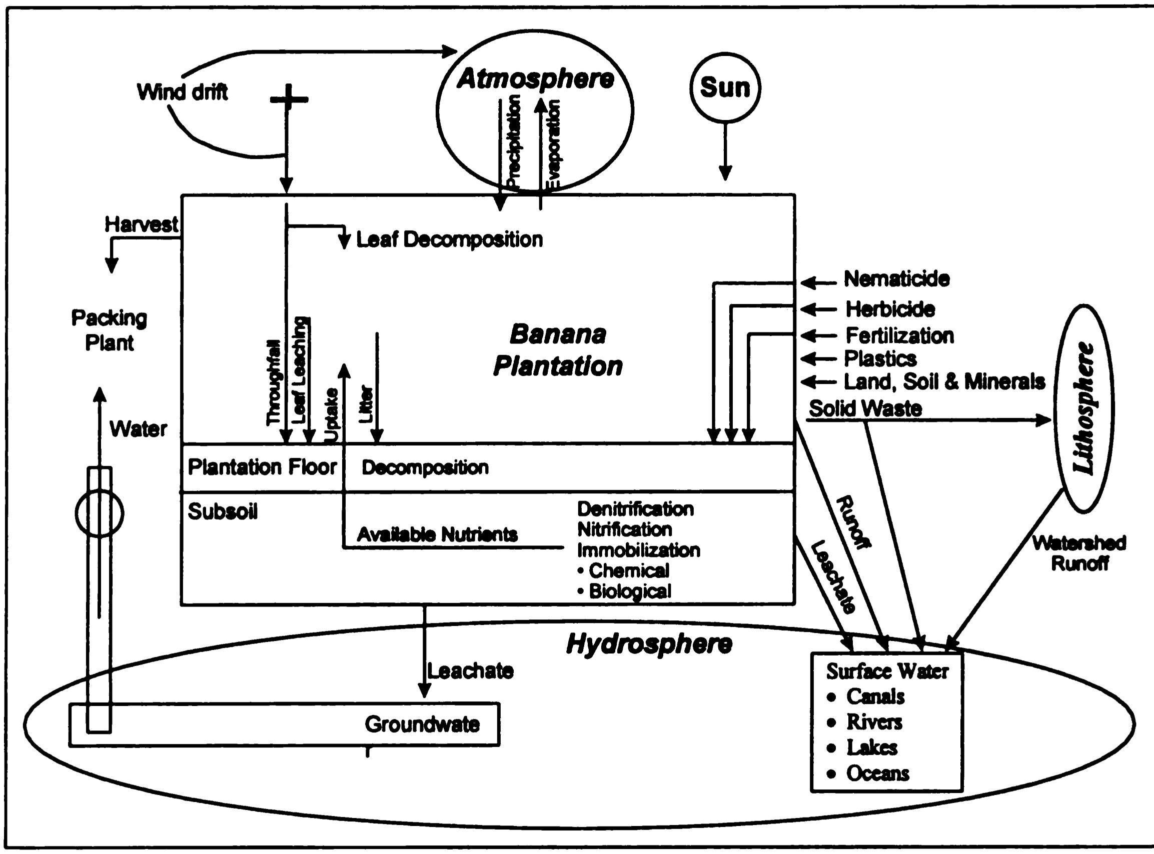

Figure 14 - Micro Level Banana Production Model

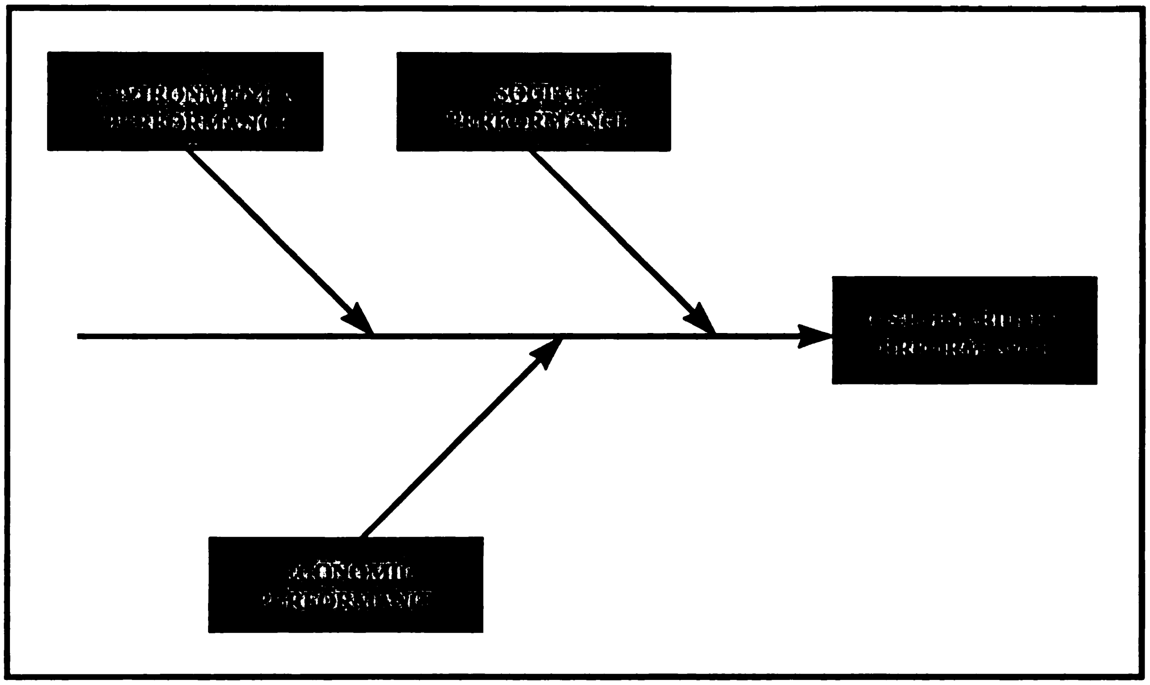

Figure 15 - Mega Elements of a Sustainability Performance Index.

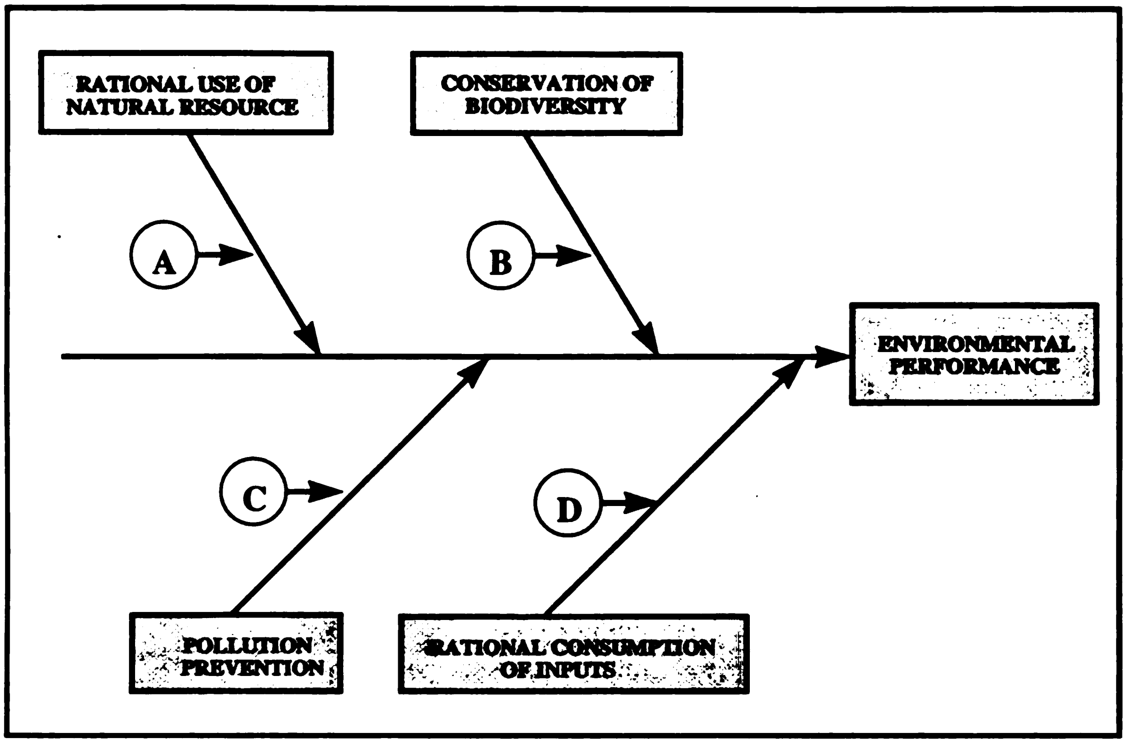

Figure 16 - Macro Criteria for an Environmental Performance Index.

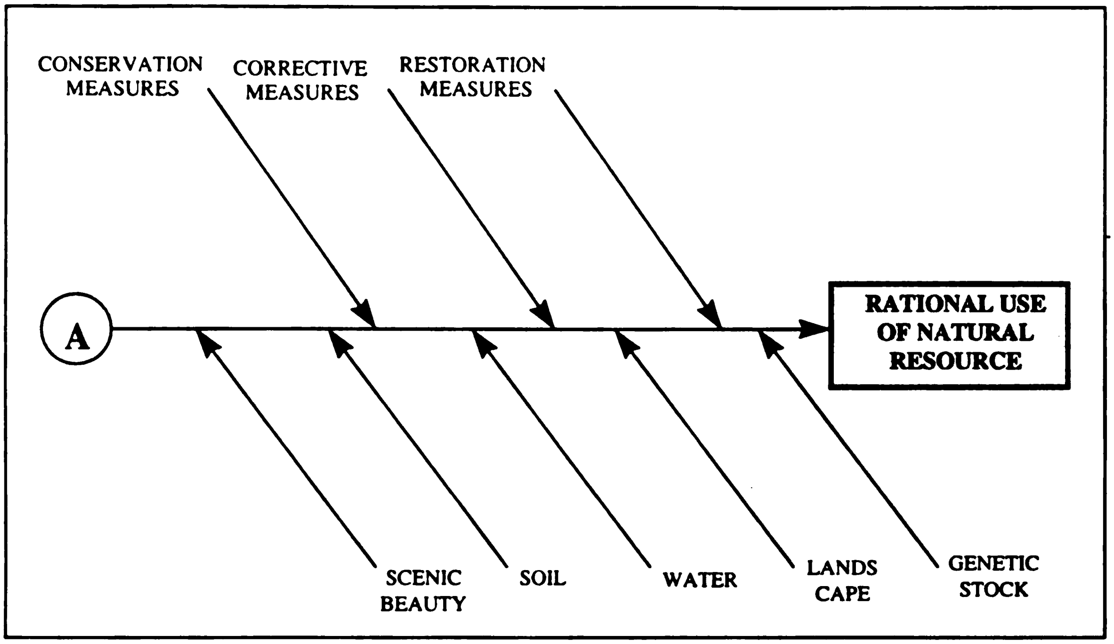

Figure 17 - Micro Criteria for an Environmental Performance Index

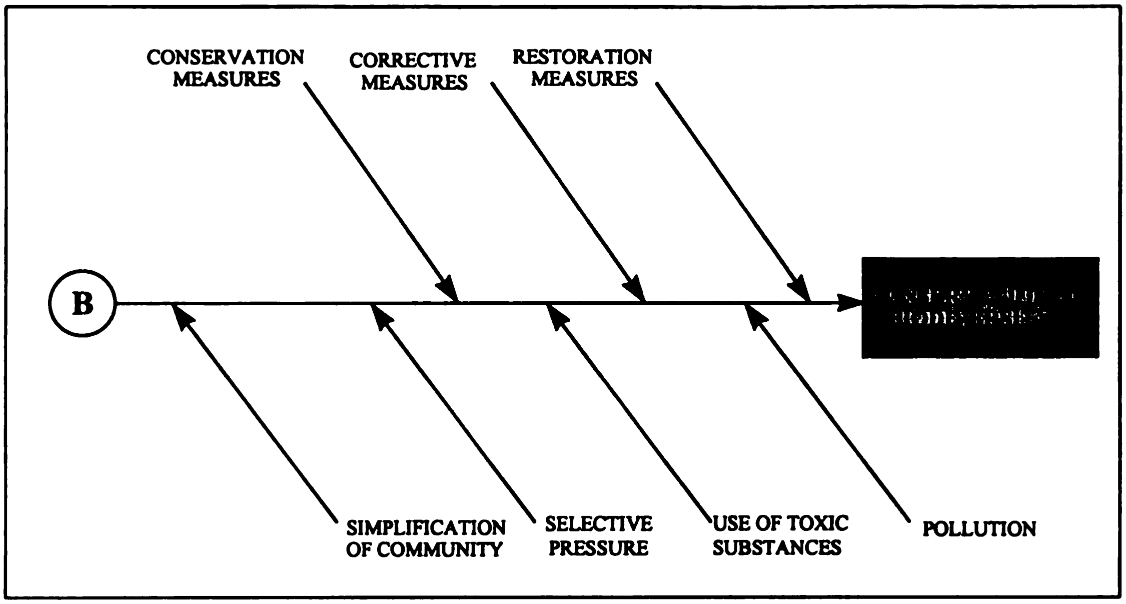

Figure 18 - Micro Criteria for an Environmental Performance Index (Conservation of Biodiversity).

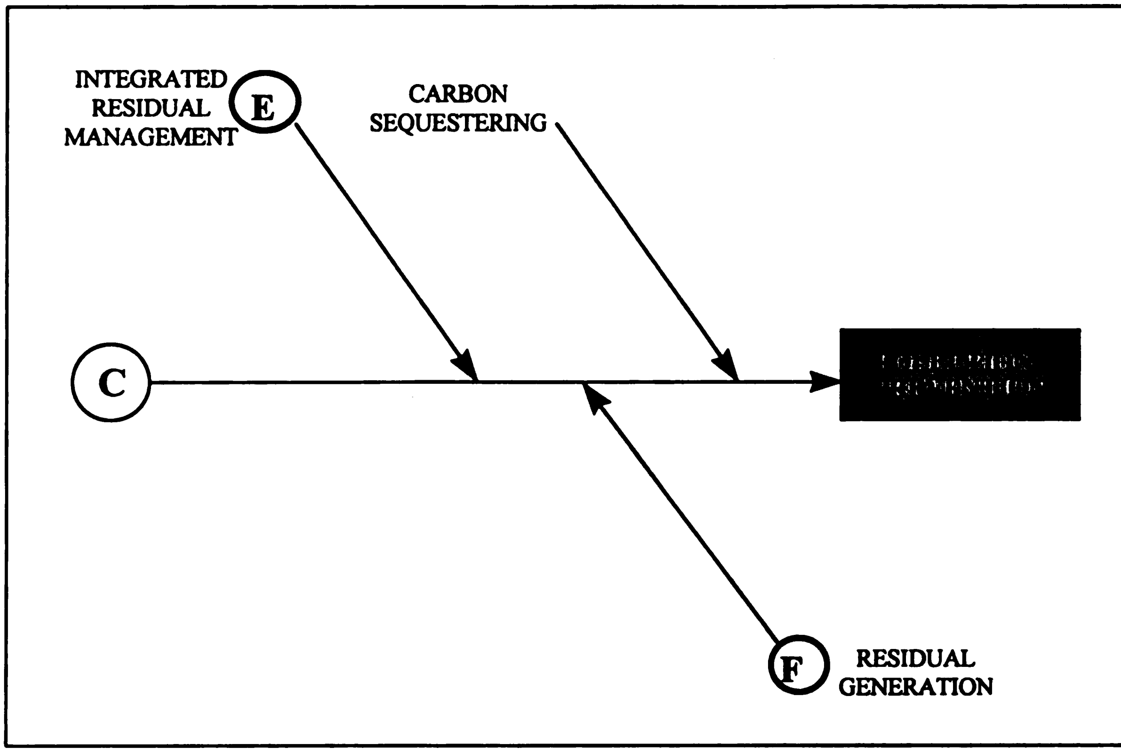

Figure 19 - Micro Criteria for an Environmental Performance Index (Pollution Prevention)

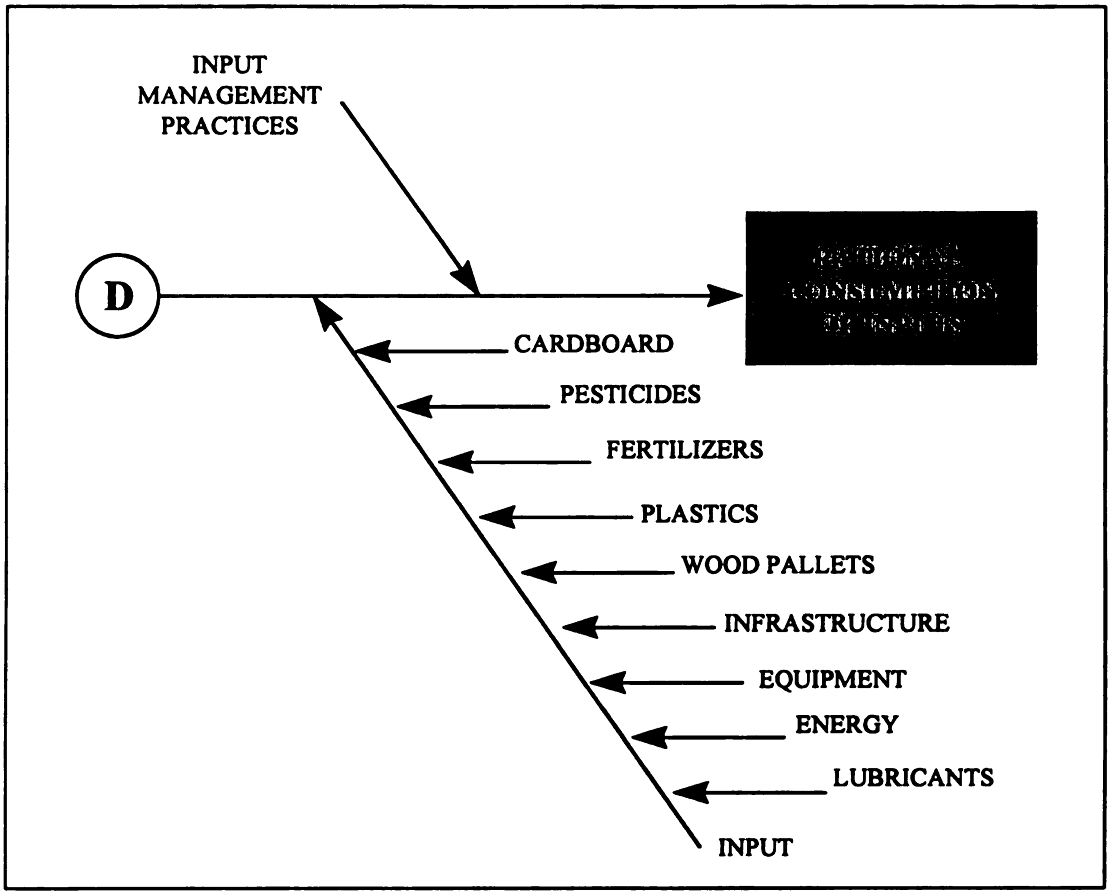

Figure 20 - Micro Criteria for an Environmental Performance Index (Rational Consumption of Inputs)

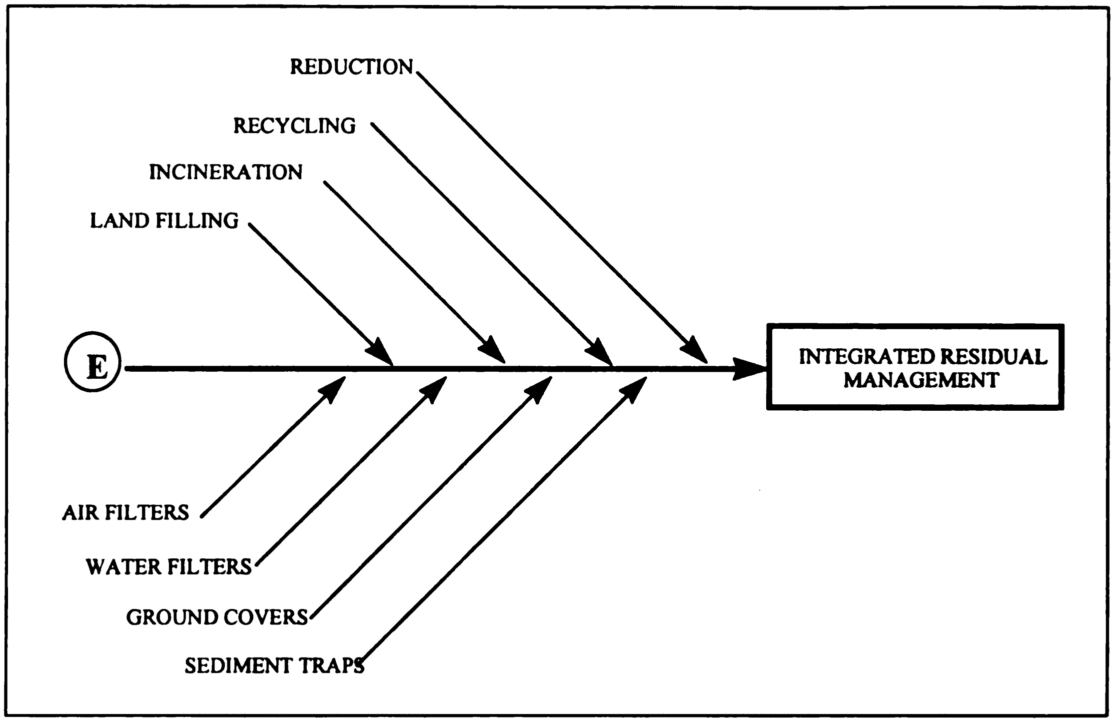

Figure 21 - Micro Sub-Criteria for an Environmental Performance Index (Integrated Residual Management)

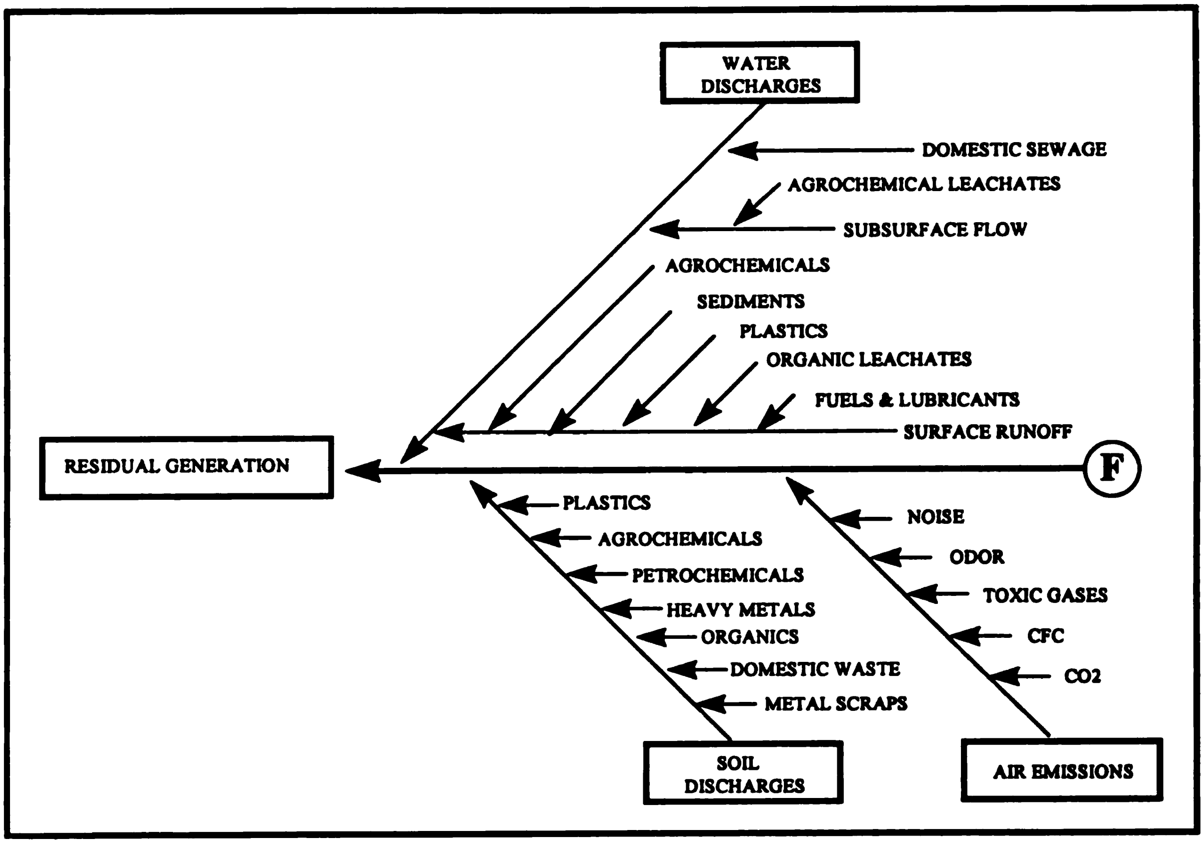

Figure 22 - Micro Sub-criteria for an Environmental Performance Index (Residual Generation)

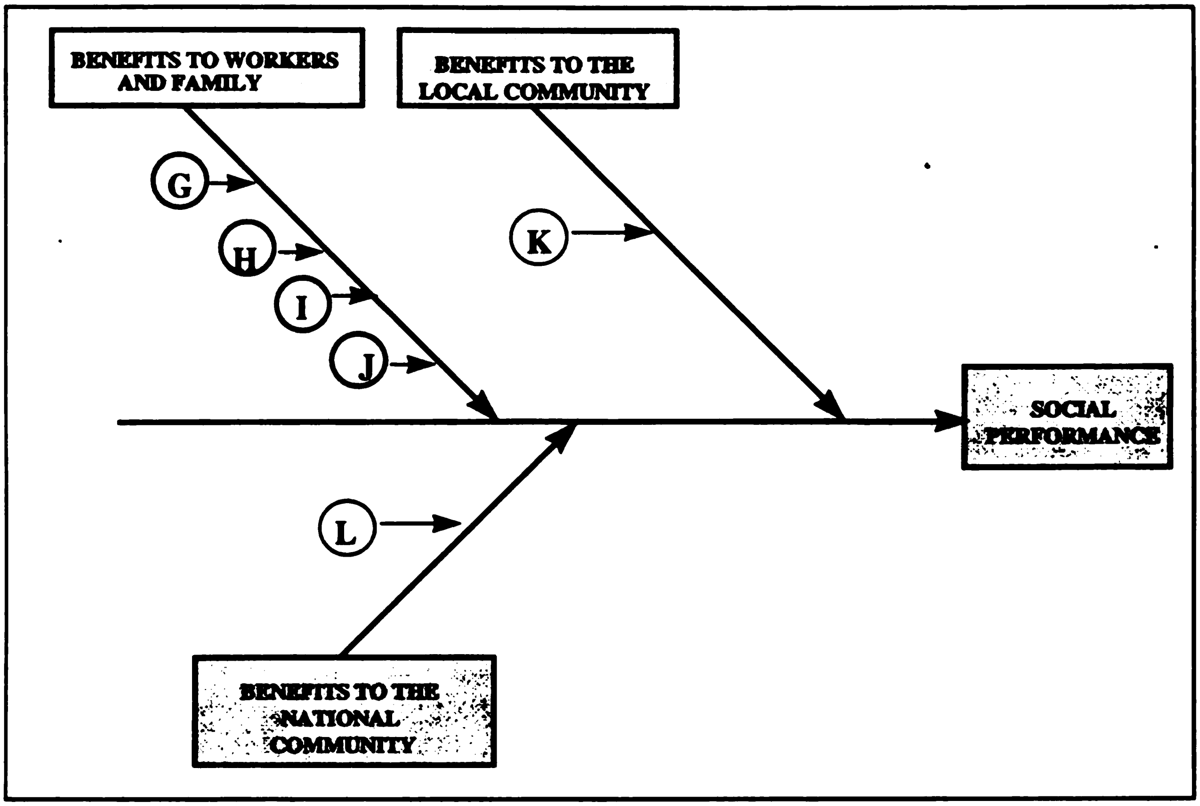

Figure 23 - Macro Criteria for a Social Performance Index

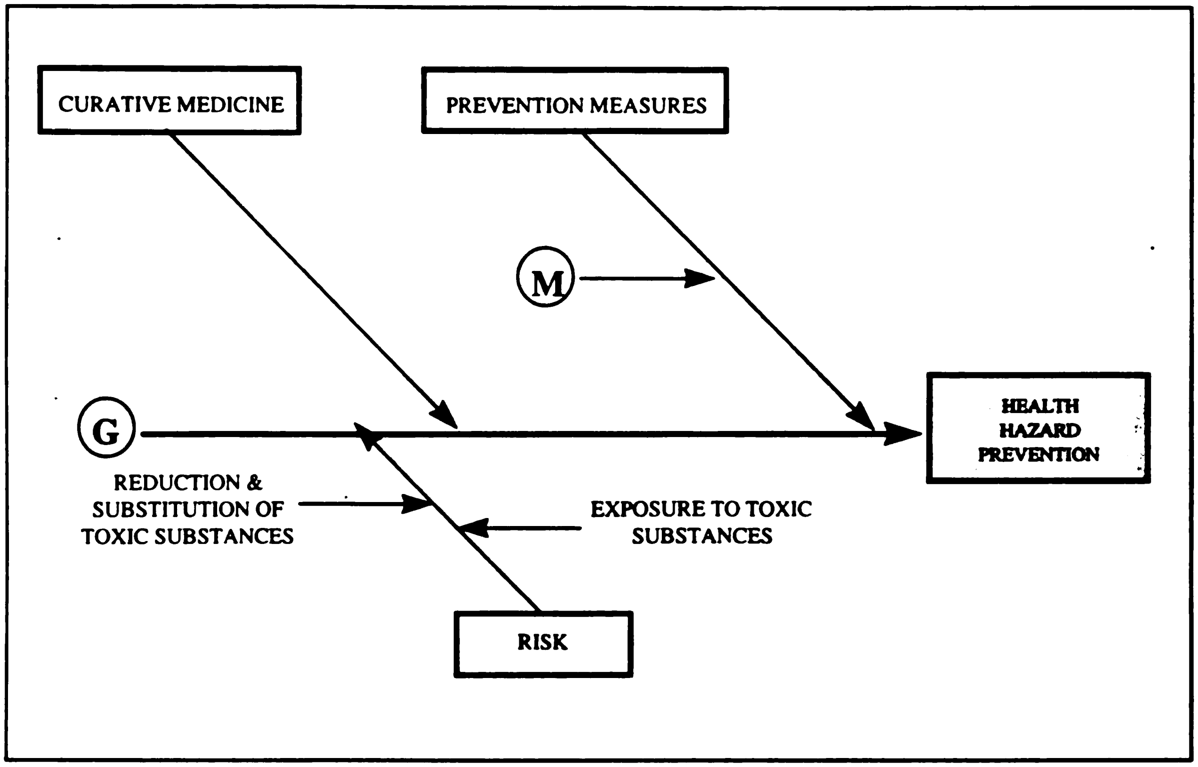

Figure 24 - Micro Criteria for a Social Performance Index (Health Hazard Prevention)

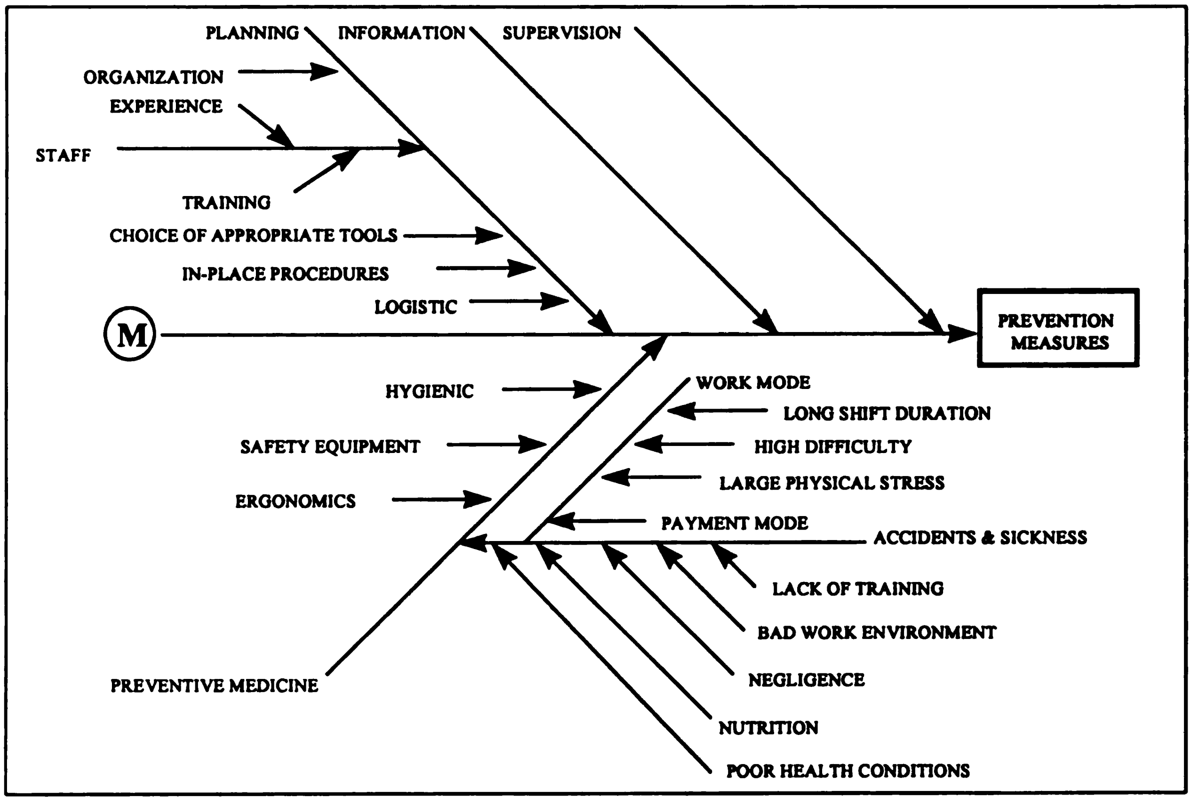

Figure 25 - Micro Sub-criteria for a Social Performance Index (Prevention Measures)

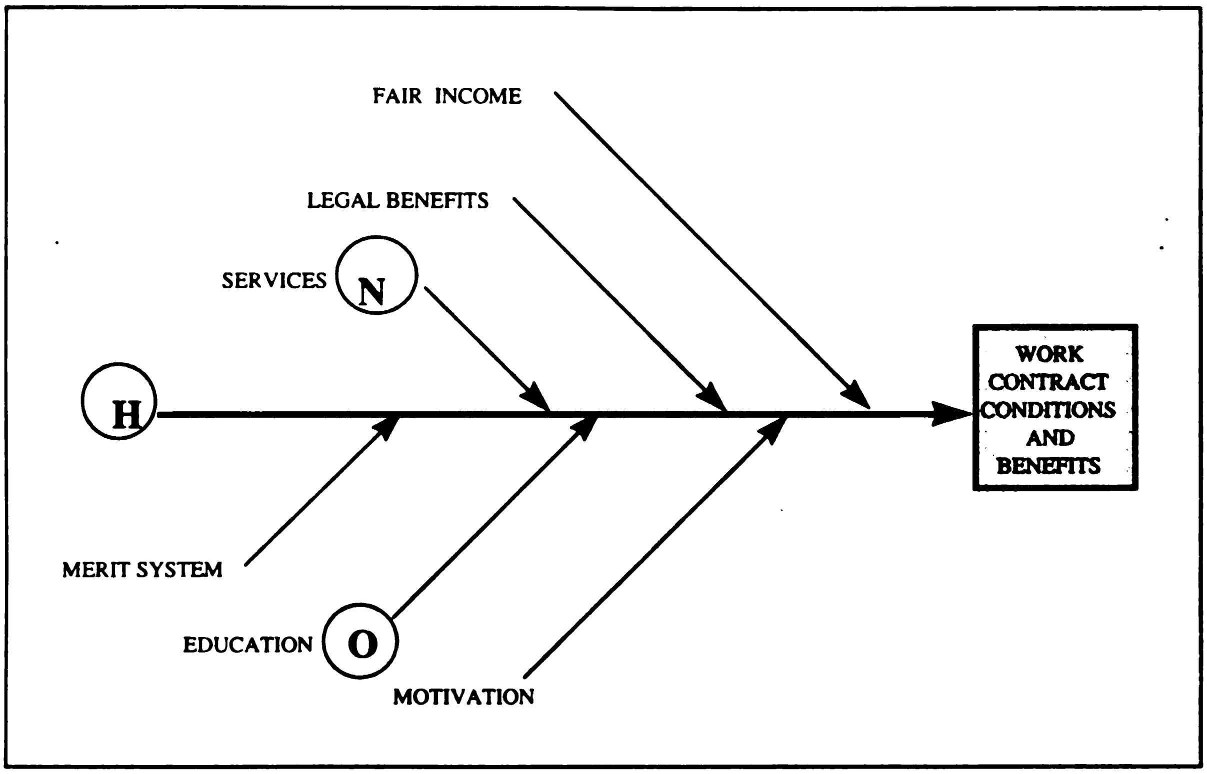

Figure 26 - Micro Sub-criteria for a Social Performance Index (Prevention Measures)

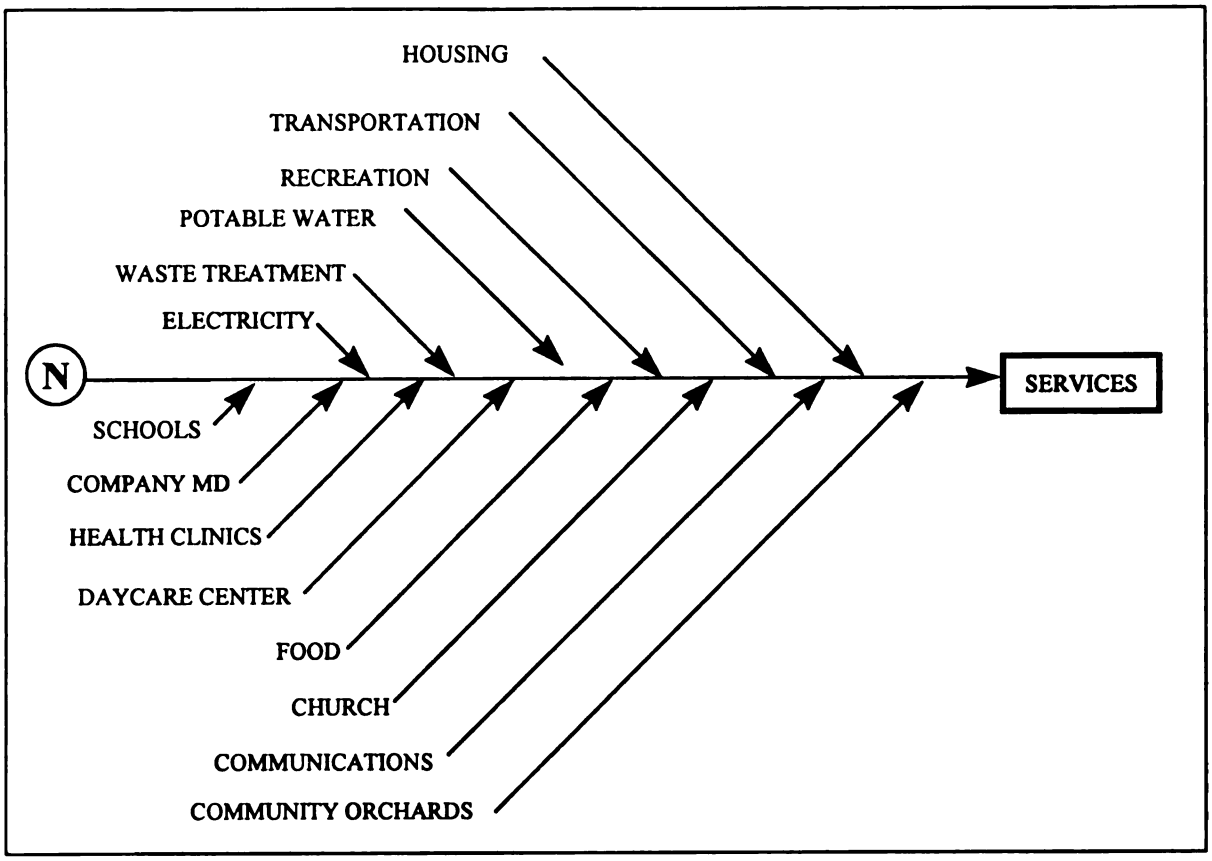

Figure 27 - Micro Sub-criteria for a Social Performance Index (Services)

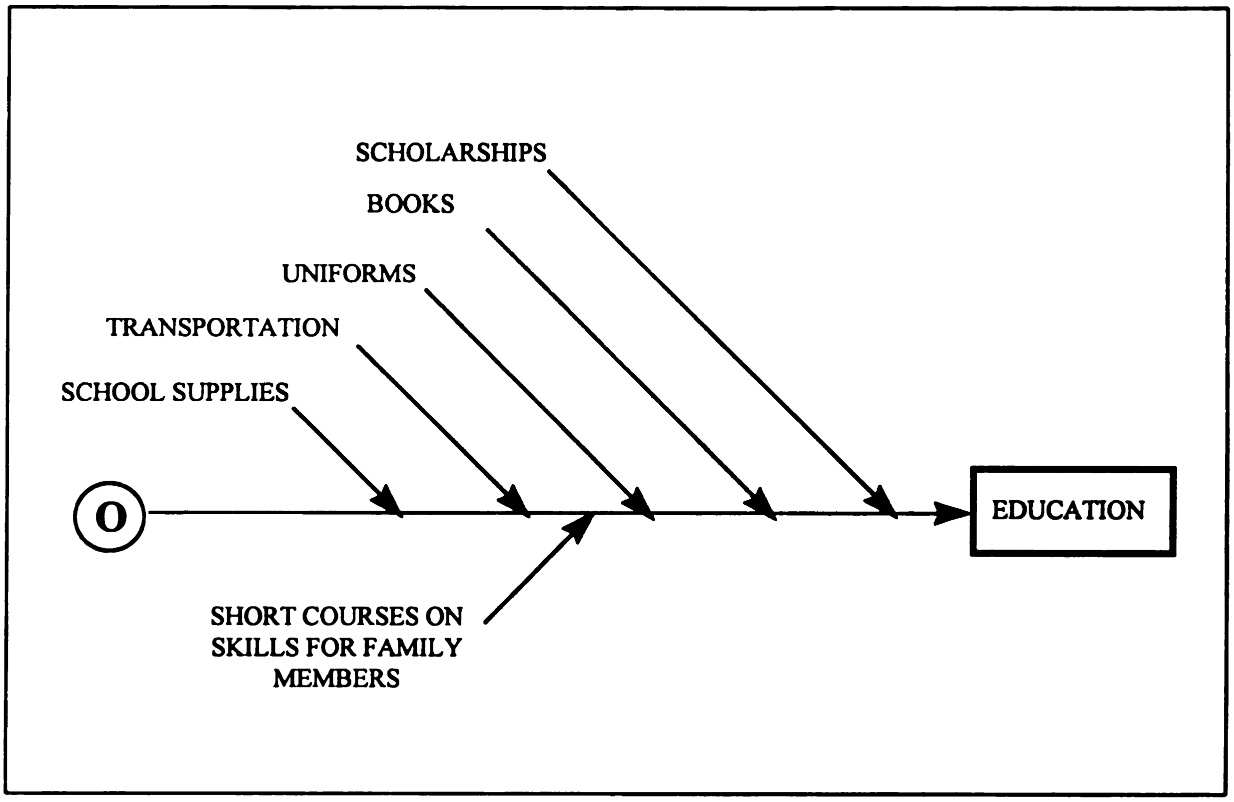

Figure 28 - Micro Sub-criteria for a Social Performance Index (Education)

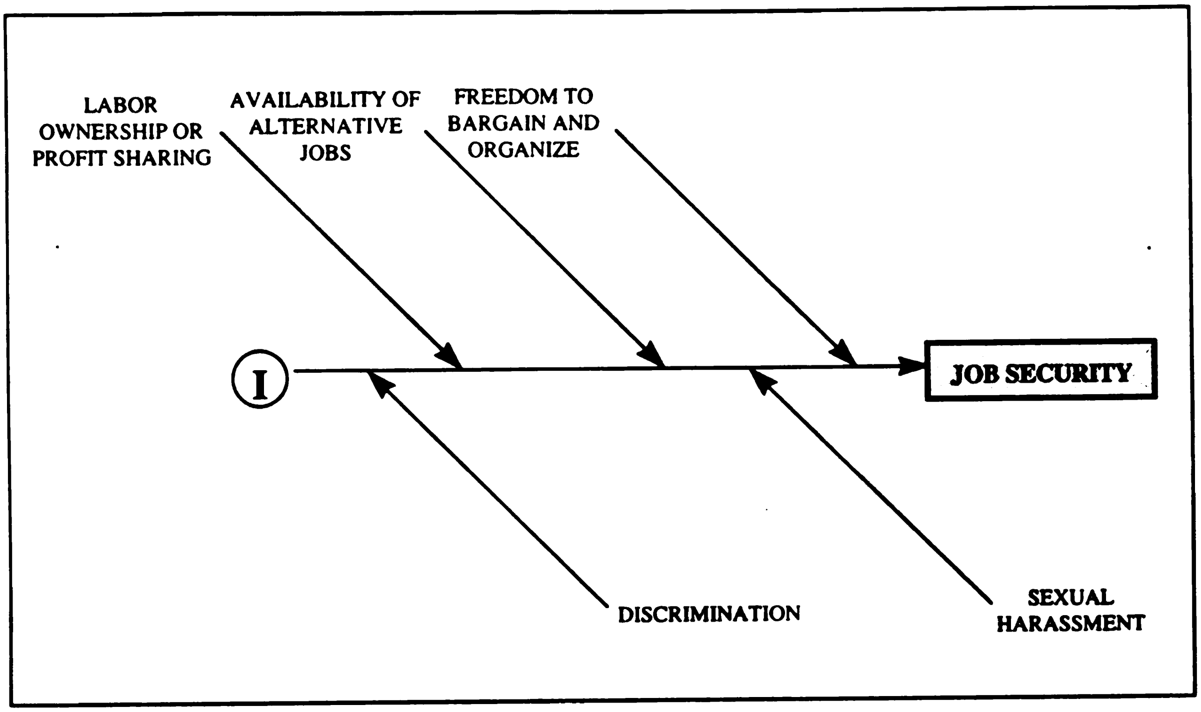

Figure 29 - Micro Criteria for a Social Performance Index (Job Security)

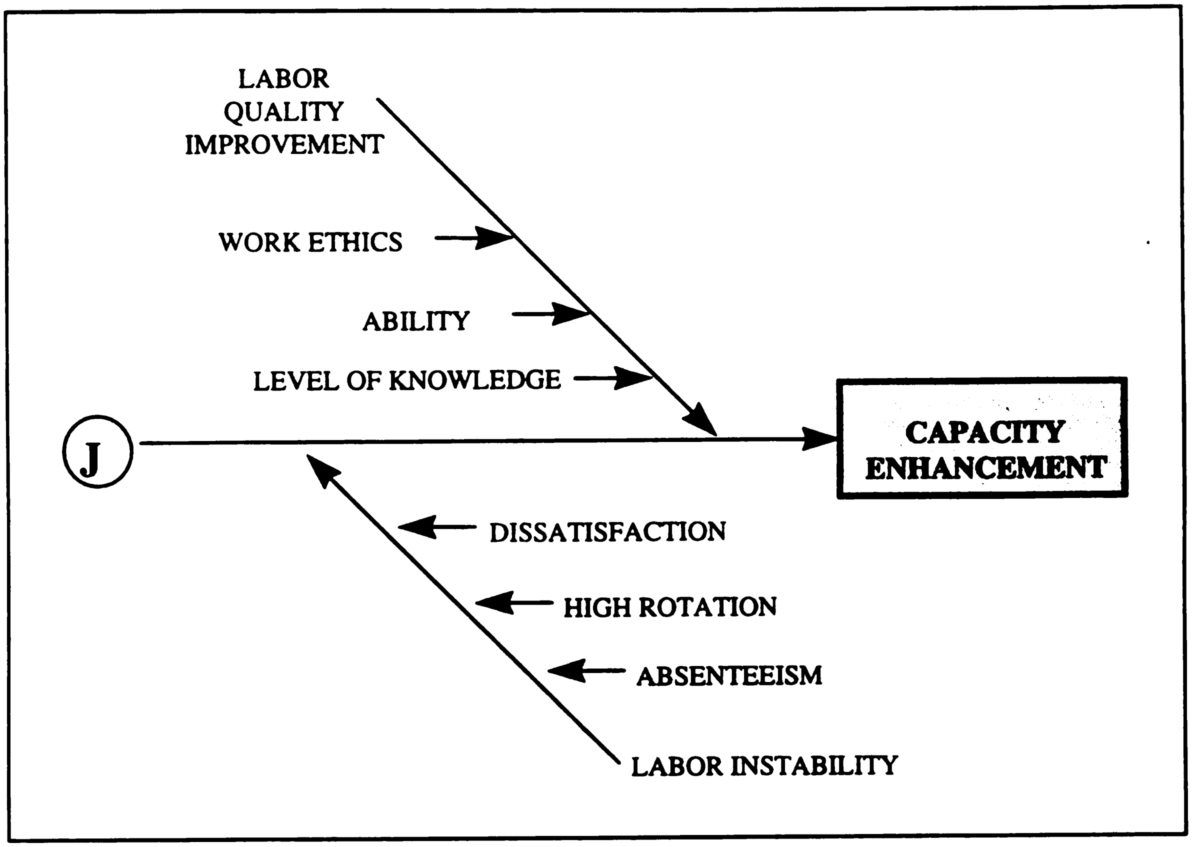

Figure 30 - Micro Criteria for a Social Performance Index

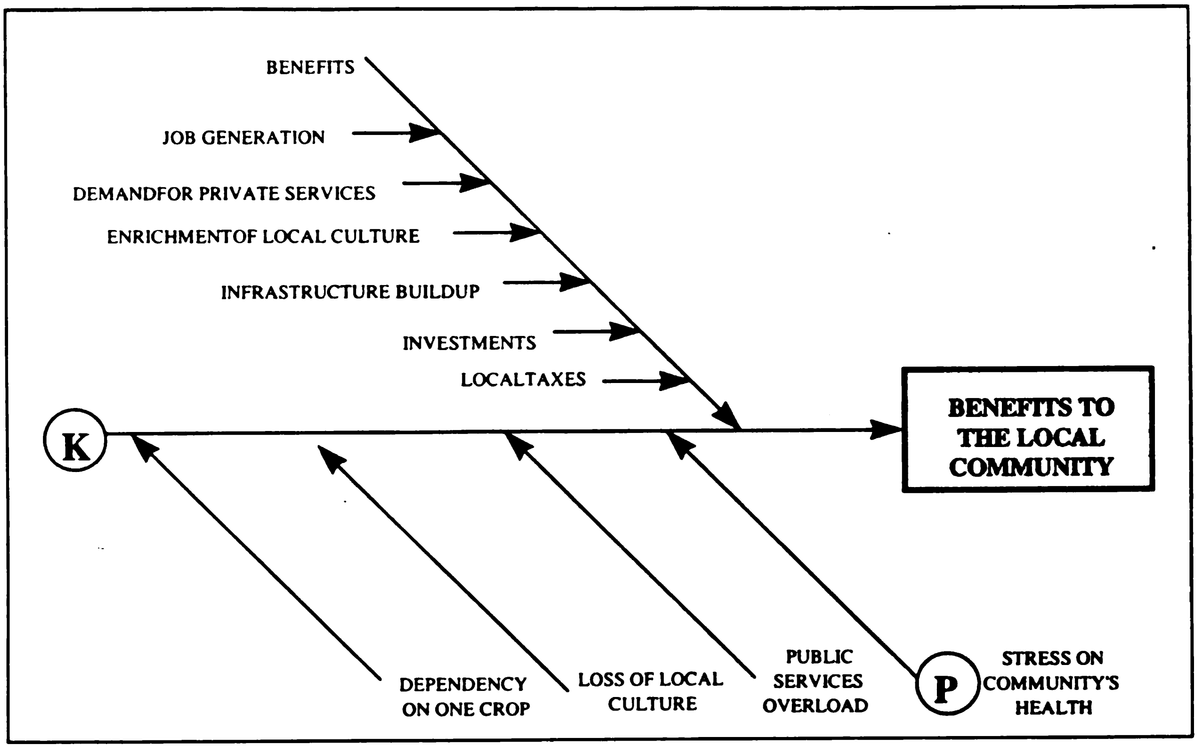

Figure 31- Micro Criteria for a Social Performance Index (Benefits to Local Community)

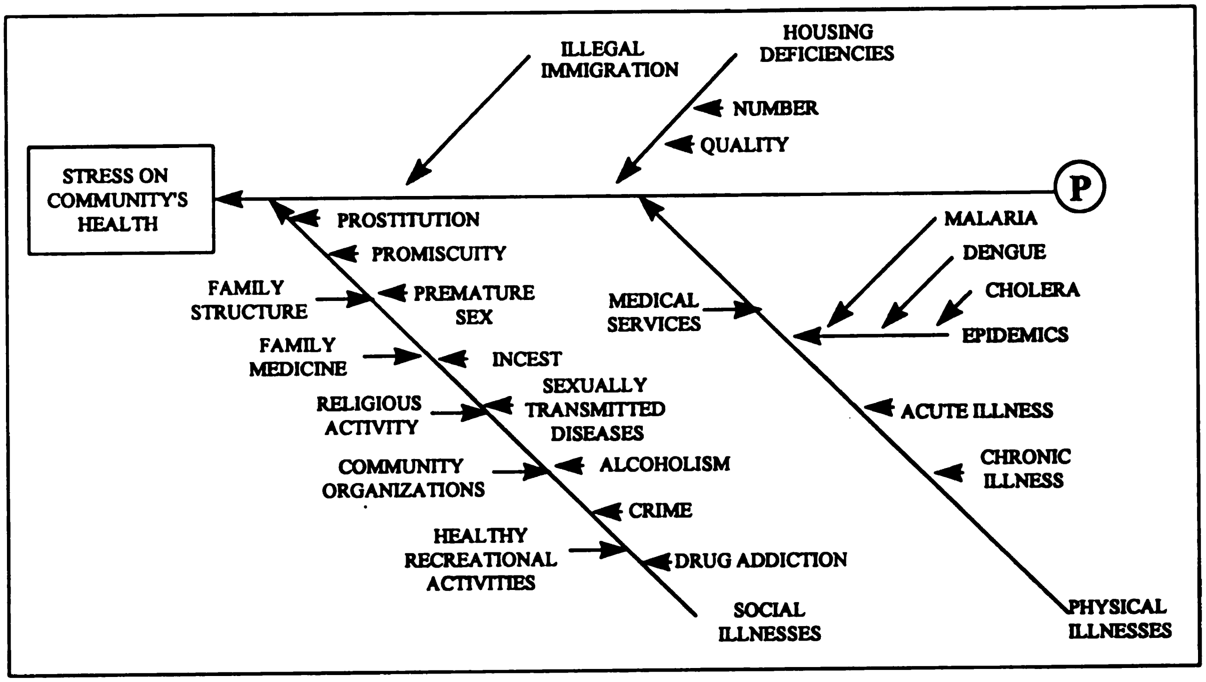

Figure 32 - Micro Sub-criteria for a Social Performance Index (Stress on Community's Health)

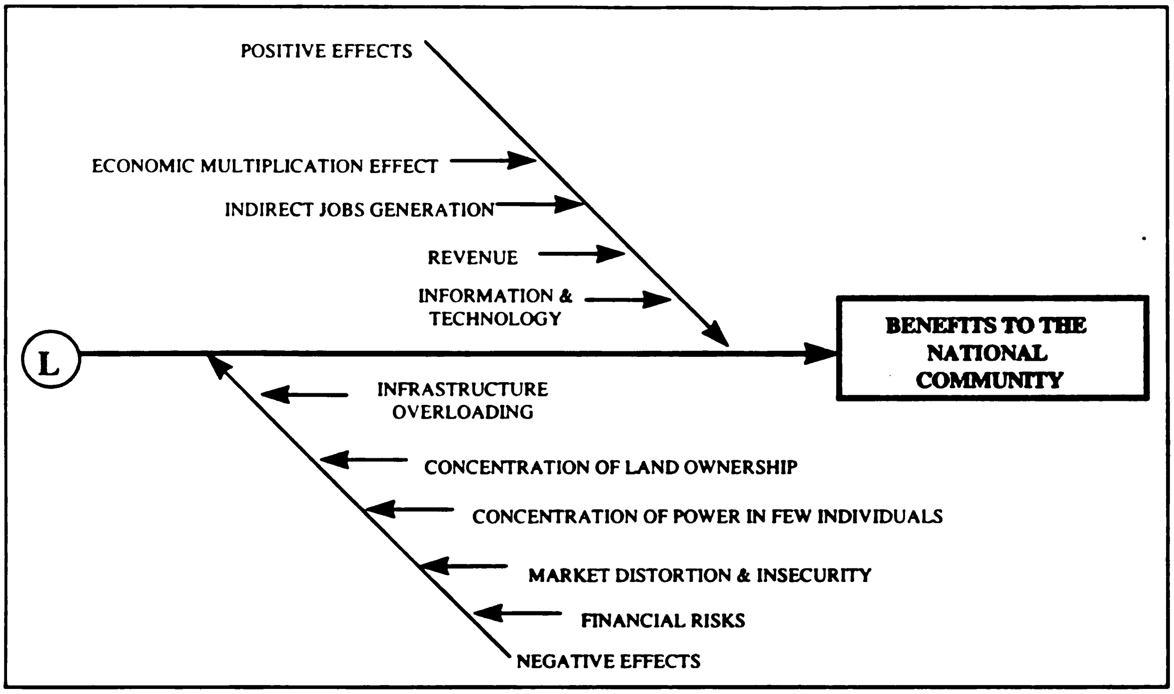

Figure 33 - Micro Criteria for a Social Performance Index

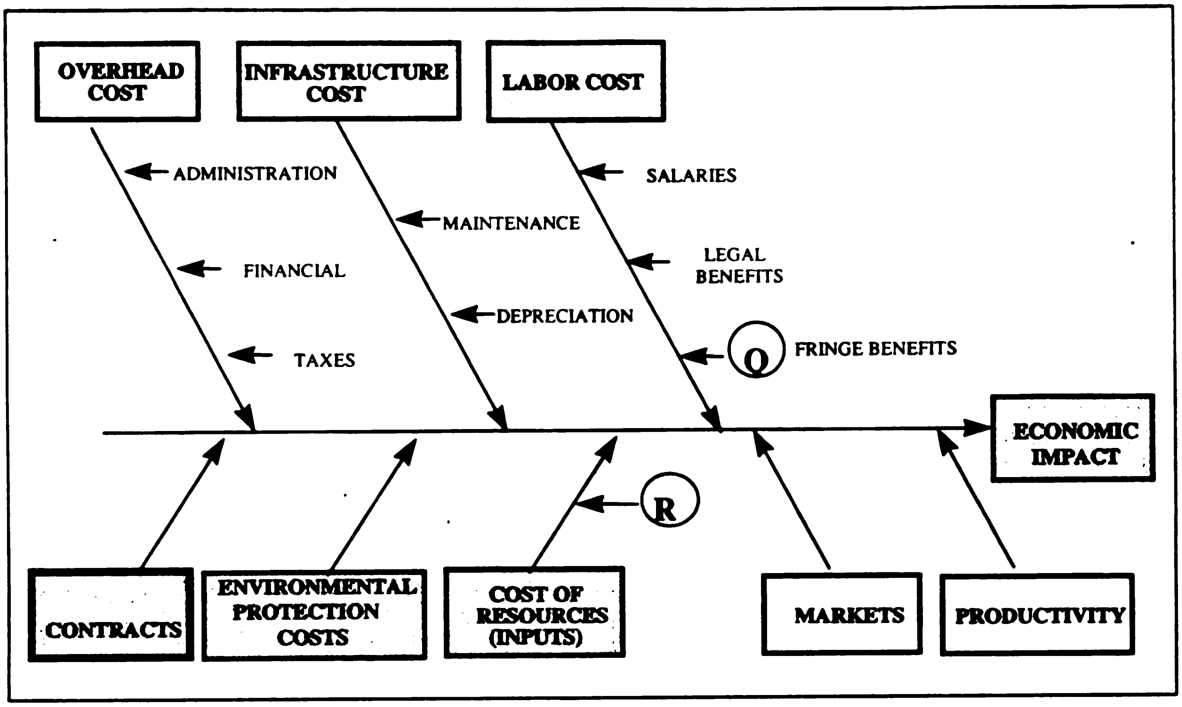

Figure 34 - Macro Criteria for an Economic Performance Index

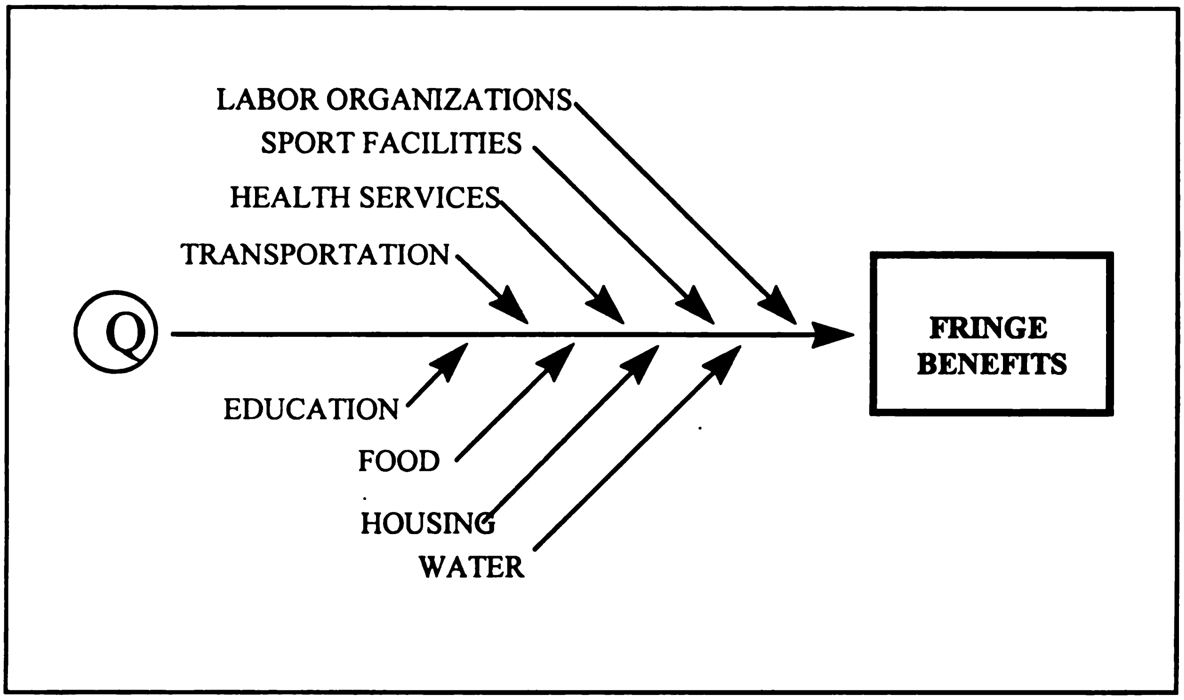

Figure 35 - Micro Sub-criteria for an Economic Performance Index (Fringe Benefits)

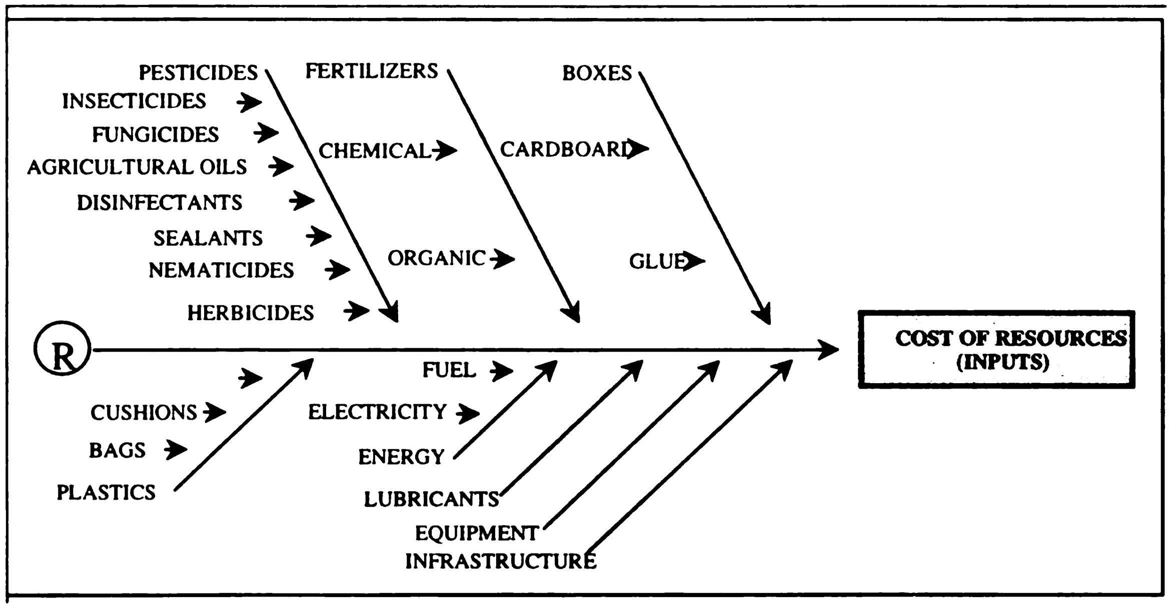

Figure 36 - Micro Criteria for an Economic Performance Index

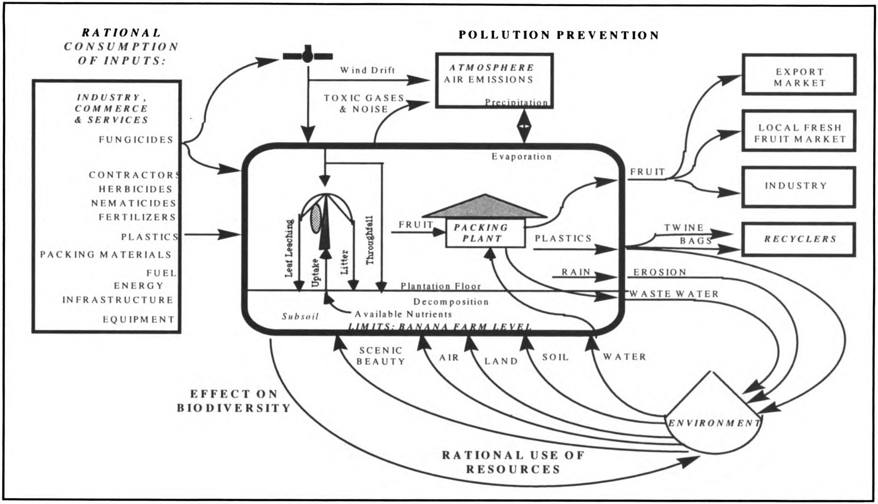

Figure 37 - Environmental Component of a Banana Production System

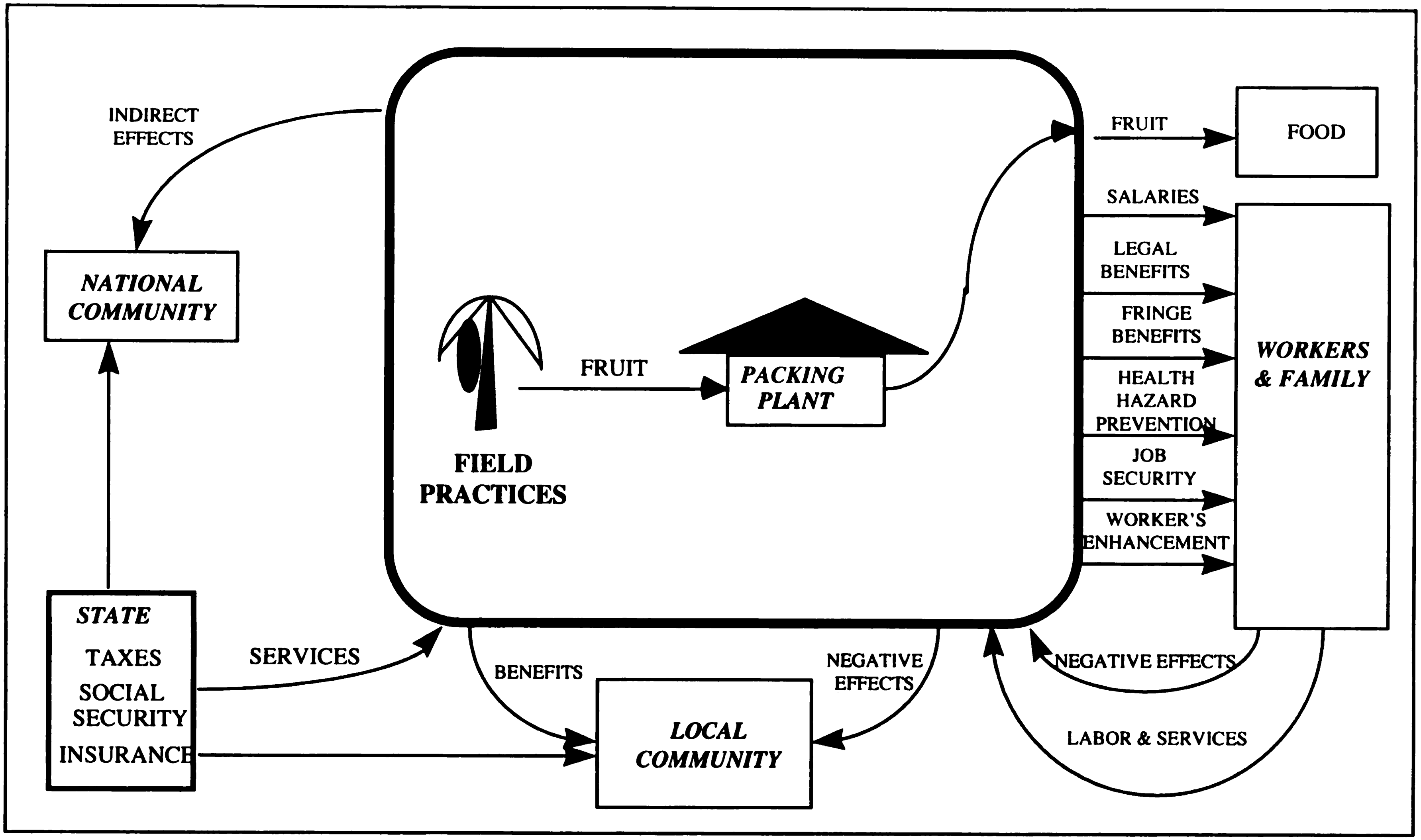

Figure 38 - Social Component of a Banana Production System

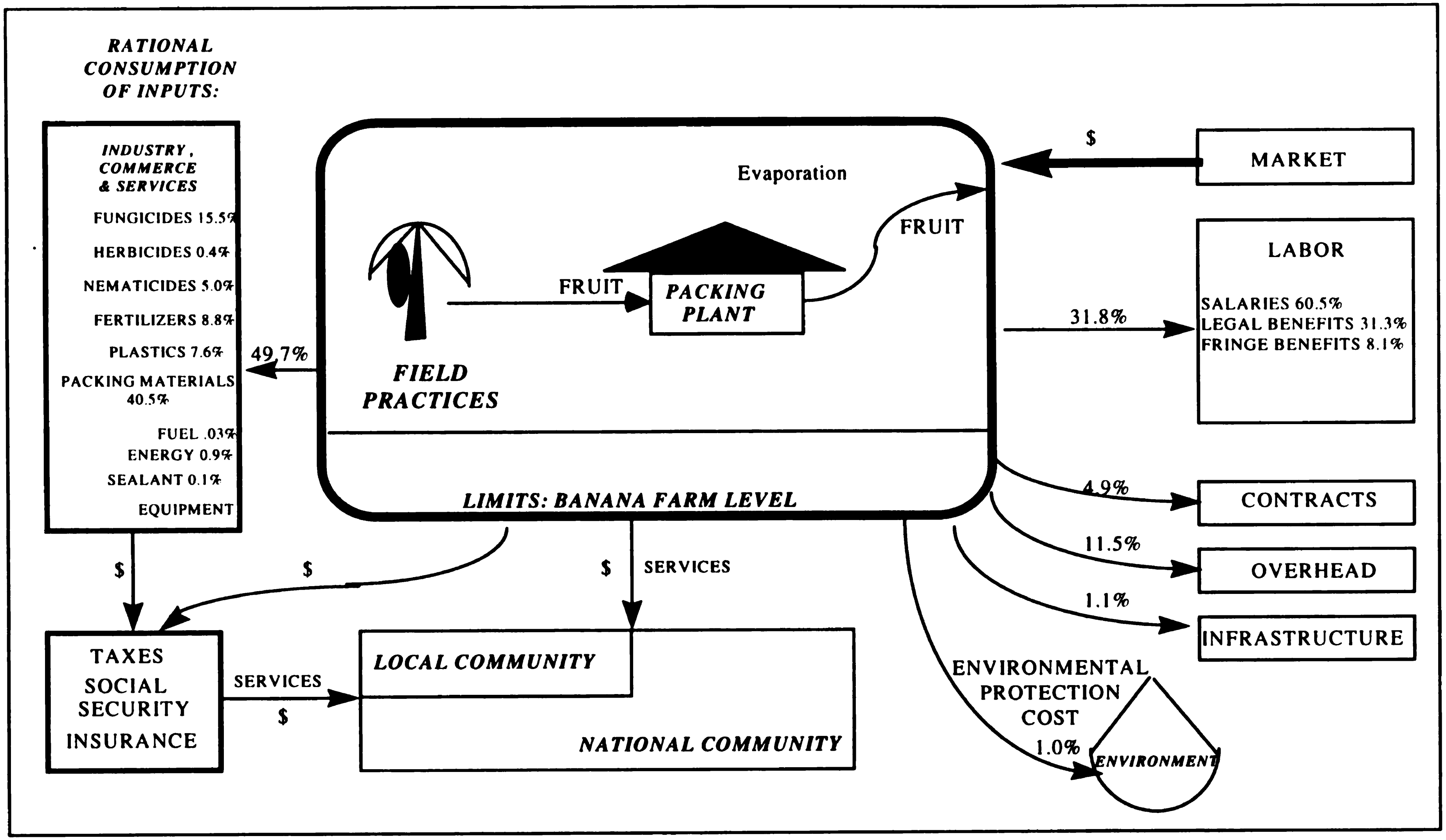

Figure 39 - Economic Component of a Banana Production System

APPENDIX B

Table 34 - Agreement to Participate

PANEL MEMBER Nº: __________ DATE: ______________

PROJECT DESCRIPTION

Many developing countries depend largely upon cash crops for hard currencies. This strategy has brought economic benefits to these countries and to many individuals, but it also has had a negative impact on the environment and society. This dissertation defined a vision, a blue print to guide those responsible for agro-production systems to see the world as a complex system that requires responsible stewardship, and to aid them in choosing production practices that minimize the impact on the environment and society while maintaining an acceptable level of economic benefits. It sets sustainability and sustainable agricultural production as its aim.

This dissertation examines Costa Rica's world-class banana production appraising its current production system and exploring alternative production techniques. It develops a systematic method of valuing and accounting impacts using a panel of experts for assessment. The method under scrutiny aids to dissect the problem by identifying cause and effect relationships of the different tasks required to produce world-class bananas, assessing the relative importance of each relationship, and accounting for their contribution to environmental, social and economic sustainability. As a result, it points out tasks that demand change, and areas that require further research and development.

This thesis contemplates the following issues:

- Any agricultural practice introduces a disturbance in the ecosystem and has a resulting impact on the environment. The environment has the resiliency to assimilate a limited amount of this impact.
- Conventional world-class banana production introduces a massive disturbance in the ecosystem, and its impact may be beyond the limits of environmental. Therefore, conventional world-class banana production may not be environmentally sustainable.
- Conventional world-class banana production brings benefits to the workers and their families, but it also has negative impacts that may be partly responsible for some of the serious social problems evidenced in the surrounding communities. Furthermore, world-class banana exports require a large national investment that generates a substantial economic beneft compensate the impact that production has on the environment and society. Therefore, conventional world-class banana production may not be economically sustainable.

Consequently, the conventional world-class banana production system used in Costa Rica may not be sustainable and it may need substantial modifications.

You are a distinguished expert in world-class banana production and have much to contribute in the development of this project. For this reason, you are being asked to be a member of the panel of experts that will assess the different tasks performed in the production of this important commodity for Costa Rica.

STATEMENT OF INFORMED CONSENT

I have read the project's description and I understand that:

1. The time required for each of three interviews is about 90 minutes each and that there is no payment for my participation.
2. The nature of my participation includes answering questions and discussing with the investigator a series of issues relating to the impact of banana production practices on the sustainability of the system.
3. My participation is entirely voluntary and I may terminate my involvement at any time without penalty.
4. My identity will only be known to the principal investigator and a limited research staff. My identity will be kept confidential and the report of research findings will not permit associating me with specific responses or findings.
5. All data collected are for research purposes only.
6. There is no foreseeable physical, psychological, social, legal or economic risk associated with this research.
7. If I have questions about the research, or I need to talk to the researcher during or after my participation in the study, I can contact the researcher by calling (506) 255-2000, extension 2900 or by writing to: Carlos E. Hernández PO. Box 4442-1000, San José, Costa Rica.

I fully understand the scope of this project and I declare my consent to participate as a member of the panel of experts.

Expert's Signature: ____________________ Date: ________
Principal Investigator's Signature: ____________________ Date: ________

Table 35 - Independent Variables

N°	CONVENTIONAL PRACTICES	N°	ALTERNATIVE MANAGEMENT PRACTICES
	FIELD PRACTICES		
CCP 1a	PLANTING AND CONTROL OF POPULATION - Bananas are managed as a perennial crop and are grown as a monoculture. The density is 1700 to 1900 plants per hectare depending on the texture of the soil. The spatial arrangement of the plants is in a hexagonal form to facilitate the support of the pseudostem, the shifting of units of production over time, and to maximize solar energy and space.	APP 1aa	Plant part of the plantation as an annual crop with the harvest schedule coordinated with periods of highest prices. Plant in high densities (2,200 - 2,400 plants per hectare) with a double row spatial arrangement.
		APP 1ab	Divide the area of production into 11 parcels. Totally renew one parcel per year.
	Seedlings free of nematodes and diseases are obtained through *in vitro* laboratory propagation, from shoots grown in nurseries, or from normal seeds. The selection of a ratoon from among the suckers is done through a process known as ratooning, the purpose of which is to select the unit of production. There are various systems of production and schemes for defining the unit of production. One of the most common is the designation of the mother, daughter, and granddaughter as the unit of production. This process is accomplished in 6- to 8-week cycles. The daughters are selected according to their vigor and location (distance between units of production). This process has been well-studied and manuals exist that describe the task.	APP 1ac	Rotate areas that do not meet the minimum established level for efficient production. Define a minimum acceptable level of production and biological saturation, considering the following parameters: high population of nematodes, infection of black Sigatoka, and low population density. Maintain uncultivated areas of the plantation in fallow for two years. Grow legumes in the fallow areas to fix nitrogen. Incorporate large quantities of organic material into the soil in the fallow areas (5-6 tons per hectare per year). In this manner, the system of monoculture is broken and a mosaic of vegetation is introduced in the banana plantation. Furthermore, it breaks the growth cycle of pathogens.
	However, selection in the field is done on the basis of the experience of the worker and is very subjective. To maintain the desired spatial arrangement and population density, poorly located, weak or damaged units of production are identified and removed. Planting and replanting are done manually.	APP 1ad	To renew the areas in production, plant the seedlings in bags of compost and-or bokashi (4 kg per bag). When transplanted to the field, this process incorporates a large quantity of organic matter into the soil of the plantation. In addition, the seedling will have greater vigor and resistance to disease and pests.

CPP1a	GROWTH AND CONTROL OF POPULATION (cont'd) - Some plantations sterilize the soil before planting using methyl bromide, which is extremely toxic.	APP 1ae	Reforest the banks of rivers, streams, springs and along roads with quick growing species of medium height.
	All the organic wastes generated in the process of growth and control of the population are deposited on the soil of the plantation as green manure.	APP 1af	Create a buffer zone at least 15 m wide around the perimeter of the plantation. This zone should be planted with native species to restore the ecosystem and improve biodiversity.
CCP1b	FIELD PRACTICES DRAINAGE In Costa Rica, bananas are grown in regions with a hot, humid climate. Precipitation in these zones is between 1500 and 3500 mm per year and the temperatures fluctuate between 24 and 30 degrees Centigrade. The terrain is relatively flat.	APP 1ba	Design the drainage system using engineering methods to balance the following parameters: a) the probability of rainfall that will exceed the capacity of the drainage system, b) construction costs, c) operation costs, d) and the cost of damage caused by flooding.
	Due to these conditions, an extensive drainage system is required for the optimal development of the banana plant. Topography and soil type, along with precipitation volume, determine the design of the drainage system. Drainage is classified as superficial or subsurface. The first type is used to drain excess water from the surface of the plantation, and the second maintains the groundwater table at	APP 1bb	Install subsurface drainage system using perforated plastic tubing to drain the areas between the secondary canals in order to reduce erosion and leaching and to avoid accidents. The initial cost of this practice is high. Note of caution: Subsurface drainage systems were seriously damaged in the earthquake of 1991.
	a depth of no less than 1.80 meters. The majority of plantations have an open network of primary, secondary, and tertiary canals. A few plantations use	APP 1bc	Plant renovated areas by shaping the floor of the plantation into domes to improve the system of superficial drainage.
	subdrainage ditches with perforated plastic tubing. The extensiveness of the canal system contributes to the risk of soil erosion in the banana plantation, the transport of	APP 1bd	Plant and maintain a cover crop on the floor of the plantation.
	agrochemicals away from the plantation, and the leaching of nutrients from the soil. Fortunately, most plantations are located in areas with small slope. Soil erosion is further mitigated by the deposit of organic residues on the plantation floor.	APP 1be	Construct sediment traps in the secondary and tertiary canals.

CPP2a	CONTROL OF PESTS AND DISEASE CONTROL OF BLACK SIGATOKA Good cultural practices constitute the first line of defence against black *Sigatoka*. A good drainage system, sanitation measures, weed control, and monitoring of climate and the disease reduce the degree of infection and chemical use. In addition, infected leaves or parts of the leaves are removed weekly to reduce the inoculate. Dead leaves are also removed to eliminate insect habitat and protect the fruit.	APP 2aa	Establish integrated control programs (protectants, systemics, and oil). These programs should be obligatory and regulated by a commission with representatives from producers, agrochemical companies, and government agencies. The purpose of this process is to reduce resistance and inoculation on a regional scale. The programs should be designed upon the results of field research conducted by zones and areas of production.
	However, the aggressive nature of this fungus necessitates the frequent application of fungicides to maintain productivity and quality. Fungicides to control black *Sigatoka* are applied with aerial spraying. The transnational grower-buyers have their own control systems. Most of these companies operate their own equipment and have their own airport facilities. Other transnational companies contract services with national	APP 2ab	Introduce monitoring techniques for prediction and methodology for decision making based on the ecology and biology of the plantation, the characteristics of the fungus, and climatic conditions. These systems study the level of pressure of the disease and its state of evolution, consider climatic conditions, determine the probability and extent of damage, and recommend corrective measures.
	spraying companies and rent airport facilities. Most independent producers cannot afford to own their own planes and operate airport facilities. Independent producers have the option of choosing the control system and the spraying company. However, the quality of the fruit is controlled by the	APP 2ac	Combine the aerial spraying system with subfoliar spraying using equipment with electrostatic dispensers. Modify the support system to permit this technique. Use adequate protective equipment.
	transnationals who buy the fruit, and the quality depends to a great extent on the control of black Sigatoka. To avoid quality problems and to ensure a good service, many independent producers consider more convenient to contract with the transnationals the planning and implementation of control programs for their plantations. Since the transnational grower-buyers have adequate technical support and monitoring, this arrangement helps ensure that only approved products are used for aerial spraying.	APP 2ad	Use biological controls for prevention (i.e., enhanced microorganisms that competition - EM) and treatment (i.e., serratia that attacks the cell wall of fungi).

	CONTROL OF BLACK SIGATOKA (Cont'd 1) The frequency of spraying is from 28 to 45 cycles per year and represents 12 - 16% of the costs of production. The fungicides sprayed are either systemics or protectants. Resistance to systemics has been reported. The products are mixed according to the purpose of the control. The principal products used are: Triazoles, Benimidazoles, Mancozeb, Clorothalonill, Morfolinas and agricultural oil. Most control programs include 50 - 75% of the applications with Mancozeb. The rate of application of the systemic fungicides is approximately 100 grams of active ingredients for each 20 liters of inert liquid per hectare. The protectant fungicides require a much higher rate. All the fungicides used, with the exception of Calixin, are approved by the EPA and must meet strict testing guidelines for persistence and biodegradability. Calixin is not registered with the EPA because it is not used for agriculture in the United States of America. It is registered in European countries. However, the EPA regulates residual tolerances on imported fruit, requiring that the chemicals pass a rigorous registration process including tests for toxicity and biodegradation. Studies have demonstrated that approximately 20% of applied fungicides is lost to drift and does not fall within the intended flight plan. In flights passes within extensive areas of plantation, the fungicide that does not reach the intended area will probably settle within adjoining plantation areas. However, fungicide drift creates a contamination problem for the areas bordering the plantation, and the degree of importance depends on the geometric layout of the plantation, the proximity of rivers and centers of population, and the flight pattern of the cropduster.	APP 2ae APP 2af APP 2ag	Use a helicopter to spray fungicides in specific places where an airplane is not effective or could cause problems. In spite of the high cost of a helicopter, it should be used when the following conditions are encountered: a. where drift can affect neighboring populations, packing plants and administrative areas, b. in adjacent areas of forest and buffer zones that present obstacles in the flight path of the airplane, c. near the perimeter of the plantation to reduce the effects of drift. Reforest a minimum strip of 15 m along the banks of rivers, streams, springs and along roads with quick growing species of medium height. Create a buffer zone at least 15 m wide around the perimeter of the plantation. This zone should be planted with native species to restore the ecosystem and improve biodiversity.

	CONTROL OF BLACK SIGATOKA (Cont'd 2) Studies conducted by the Universidad Nacional have demonstrated the presence of limited amounts of fungicides used in the control of black *Sigatoka* in waters of canals and rivers around banana plantations. Spray drift has become a major concern for the general public in the United State. As a result, a Spray Drift Task Force was created in 1994 which is studying mechanism to reduce this problem. These new and improved methods will eventually reach Costa Rica and alleviate the problem. Of the 80% of the fungicide that arrives at the intended destination, approximately 65% is deposited on the leaves. The remaining 15% passes through the canopy falls to the ground. In the case of systemics, the active ingredient is designed to be absorbed by the plant in the first 8 hours. In the case of protectants, the fungicides generally have sticking compound incorporated in the formulated product so it adheres to the leaves. Sometimes additional gumming agents are incorporated. However, it is possible that some of the active ingredient is washed off the leaves by rain and falls to the plantation floor. Depending on weed and residue management practices, part of the fungicide that falls to the ground will be deposited on dead banana tissue and vegetative ground covers (weeds). The rest of the material fall on the soil.	APP 2ah APP 2ai APP 2aj	Plant and maintain vegetative cover in the drainage canals. Spray at night using instruments for navigation and location with the purpose of assuring complete withdrawal of field workers and taking advantage of better temperature and wind conditions. Improve airport facilities, requiring the implementation of operational security measures, installing systems for recycling and containment, constructing efficient sedimentation systems, and installing clay filters to capture the active ingredient for biodegradation. Recommendations for future evaluation: Develop new molecules for chemical control. A new molecule was recently introduced and its application began after this study began. Its name is azoxystrobin. The trade name BANKIT and is produce by Zeneca. It is based on a natural antagonist to fungi probably reducing environmental impact and increasing safety. Develop and utilize resistant varieties using biotechnology and promote the marketing of these varieties.

	CONTROL OF BLACK SIGATOKA (Cont'd 3) The fungicide that falls to the ground serves to neutralize sources of inoculation that are associated with living and dead vegetative material on the plantation floor. The fungicides have a short life and were designed for rapid biodegradation. They are also fairly insoluble in water and have a high affinity for clay particles, so they are easily immobilized, reducing the probability of subsurface migration. Surface migration of the fungicide in runoff depends on the lapse of time between application and precipitation event. The fungicide that is washed will feasibly flow into the canals, where it probably precipitates out of solution and binds to the sediments. Because the chemicals have a short life and are biodegradable, fungicides that are immobilized in the sediments are presumably metabolized quickly. Further study of metabolites generated from fungicides and their fate is necessary because these by-products can have an impact on the environment.		

	CONTROL OF BLACK SIGATOKA (Cont'd 4) To minimize the risks of contamination and so that the fungicide application fulfills its objective, spraying is done only when favorable climatic conditions exist. This implies that it cannot be raining, there can be no threat of imminent rain, the temperature must be below 28-29 degrees C, the wind velocity below 4 m per second, and the relative humidity less than 70-80%. Precautions are taken to avoid spraying rivers or springs. Some plantations do not respect buffer zones for rivers, streams, and springs. The majority of plantations do not have buffer zones along roads. New plantations and some of the older plantations have begun to correct this problem, creating buffer zones for waterways as well as for roads. With few exceptions, the banana companies' facilities for mixing the product and filling the airplane are located in airports and are equipped with sedimentation tanks. There are serious deficiencies in the design of most of these systems. Some airport facilities, especially those operated by transnational companies, have equipment for recycling residues and containment systems for spills, which considerably reduces the risk of contamination.		

CPP2b	CONTROL OF PESTS AND DISEASE CONTROL OF NEMATODES Integrated pest management practices are the first line of defence against nematodes. Chemical applications are restricted to the areas having the probability of damage greater than an economic threshold, by means of a systemic inventory of nematode populations, percentage of living and dead roots, and the quantity of uprooted plants. Carbamates and organophosphates are applied. The majority of the chemicals used are highly toxic. Depending on the climate, the age of the plantation and the chemical product used, nematicides are applied from 2 to 3 times per year. Nematicides are applied in granular form containing 10-15% active ingredients and 85-90% inert. The average use of nematicide active ingredient is from 7 to 15 kg per hectare per year depending on the frequency and dosage applied. The active ingredient is only released from the granules in humid conditions. Strong rains, combined with bare soils and a good drainage system, increase the probability that the nematicides will migrate to water sources. However, the presence of granules outside the area of application is not necessarily an indication of that migration, because in general the active ingredient is located on the surface of the granule and is rapidly released. Therefore, granules found off-site may only contain inert materials. Some companies have introduced the use of refillable nematicide containers (Mocap and Rugby) to alleviate the problems of residual containers.	APP 2ba	Use biological products: a. Paecilomycis b. Plants that attract and trap nematodes, such as crotalaria. c. Biological products (enzyme extracts and natural antagonistic substances) that are safer to workers and to the environment. d. The leachate from organic decomposition is an organic material that has recently proven in laboratory tests (CORBANA) to be successful in combating nematodes. Biological control can be done in combination with existing chemicals to obtain results equivalent to those obtained using conventional methods of control.
		APP 2bb	Introduce organic material into plantation soil to promote organisms antagonistic toward pathogenic nematodes.
		APP 2bc	Apply systemic nematodes applied directly to the stump of the mother plant. The daughter absorbs the nematicide and transports it to the roots. It is necessary to investigate the level of exudation from the roots and the possibility of damaging beneficial microorganisms. In addition, it is necessary to verify that there are no residues in the fruit.
		APP 2bd	Apply nematicides directly to the roots by means of a hole made with a spike, into which a gel capsule is inserted. The hole is then covered with soil.
		APP 2be	Use application systems with returnable security packaging (i.e. Surefill).
		APP 2bf	Plant and maintain a cover crop to improve the retention of the nematicides and to reduce the risk of water contamination.

CPP4	CONTROL OF PESTS AND DISEASE CONTROL OF WEEDS In general, the floor of the plantation is maintained free of all weeds (bare). High planting density is the greatest inhibitor of weeds. Less light reaches the floor of the plantation in areas with high plant density and inhibits the growth of weeds. Weeds are controlled manually and with chemicals. Chemical control is used more frequently because it is much cheaper than manual labor. In some cases a pre-emergent herbicide is used. Cycles of herbicide application depend on quantity and type of weed. Applications are normally made every 4 to 8 weeks. The most common herbicides are paraquat, diquat, ametryn, glyphosphate, and ammonium glyfosinate. An average of 0.5 to 1 liter per hectare per cycle is applied in liquid form sprayed from tanks worn on workers' backs. To reduce herbicide applications, organic residue is left on the soil. Adequate control of the population, utilizing maximum shade, helps to minimize the growth of weeds.	APP 2ca	Plant a vegetative cover on 70 - 80 % of the floor of the plantation. The cover crop will capture nutrients and slowly liberate them after dying back. The vegetative cover effectively controls erosion and acts as a green fertilizer.
		APP 2cb	Establish an acceptable threshold for vegetative cover on the floor of the plantation and maintain the maximum acceptable cover. Partially eliminate the use of herbicides. Control weeds manually and selectively so that the remaining ground cover is free of climbing vines and other damaging species. Apply systemic herbicides that have a small environmental impact and low toxicity to humans (i.e., Finale) in periods when manual control is very expensive due to high weed growth pressure. This practice reduces the incorporation of toxins into the soil and the loss of beneficial microorganisms. The increase in micro and macro fauna improves the aeration and texture of the soil. Field tests of this practice have not demonstrated positive or negative changes in production. The cost is 40% more expensive, but is showing a tendency to decline. It is expected to be equal to the costs of chemical controls. The high initial cost after switching from chemical controls is due to an explosion of weed growth that requires manual control to maintain adequate cover.
		APP 2cc	The plantation soil can be covered by minicompost piles that generate organic manure and act as mulch. The frequency of formation of minicompost piles and the spreading of the resulting material prevents the growth of weeds.

	CONTROL OF WEEDS (cont'd)	APP 2cd	Cover the floor of the plantation with Saran to control the growth of weed stems. Saran has a life of 4 to 6 years depending on use and climate. This technique has been used in Israel with success.
		APP 2ce	Use low volume spraying systems for the application of systemic herbicides. The pumps are much smaller, reducing the workers' load and covering more area per tank.
		APP 2cf	Use gas torches to burn weeds.
			Warning: The manual control of weeds and the creation of open minicomposters should be avoided when there is a risk of MOKO infection. Ground covers increase the risk of snake and insect bites that may cause serious injury of death to workers. The use of manual tools for controlling weeds also increase the risk of cuts and bruises.

CPP3	FERTILIZATION Bananas are fertilized with synthesized chemical nutrients. Fertilization is applied manually. It can also be applied through the irrigation system where irrigation is needed. It is estimated that the harvest of 40 tons/ha/year removes 56 kg/ha/year of nitrogen, 24 kg of phosphate, and 220 kg of potassium. The most common quantities applied are: 300-500 kg phosphorus, 400-700 kg potassium, 80-150 kg magnesium, with the objective of maintaining the quality and size of fruit for export. Therefore, not all of the applied fertilizer is utilized by the plant. Part of the fertilizer is stored in the plant, and part is lost to leaching, runoff, soil fixation and volatilization. The fertilizer that is lost to leaching and runoff may contaminate surface and groundwater. The fertilization cycle is every 4-5 weeks, depending on the physical and chemical properties of the soil and the nutritional state of the plants (crop logging).	APP 3a	Design fertilization programs based on soil studies, the climate, and the requirements of the cultivation.
		APP 3b	Divide the necessary fertilizer into bi-weekly applications. This increases the amount of labor but decreases the quantity of fertilizer by 20 to 50%. This process minimizes the loss of nutrients during precipitation. The savings in fertilizers compensates for and exceeds the costs of the additional labor.
		APP 3c	Vary the forms of fertilizer application according to the weather and edafic factors.
		APP 3d	Use application techniques that localize fertilizer in the most appropriate locations for plant uptake.
		APP 3e	Complement fertilizers with applications of organic biological products and compost. Organic fertilizer improves the soil and therefore is a complement to chemical fertilizers. Sugar cane pulp, sugar processing solids, the skins from coffee beans, chicken manure, and/or organic residues from banana production can be used.
		APP 3f	Apply micronutrients via aerial spraying to complement normal fertilization. The micronutrients are mixed with fungicides and applied together.
		APP 3g	Apply ECO-Humus. ECO-Humus is humic acid complemented by micro- and macro-nutrients that can be applied to the leaf and/or the soil.

CPP5	FERTILIZATION (cont'd)	APP 3h	Use growth stimulators. These are biological enzymatic products that promote rapid biological reactions and improve the utilization of solar energy (i.e. Omeobios). Not all products on the market have demonstrated good results.
		APP 3l	Use fertilizer tablets that slowly release nutrients. These tablets are placed in a hole in front of the daughter by means of a hoe.
		APP 3j	Plant and maintain cover crops to capture fertilizer. The nutrients will be released slowly in the form of organic material produced through decomposition when the cover crop dies back. In addition, the cover crop reduces the velocity of surface runoff and minimizes the loss of fertilizer.
		APP 3k	Establish a buffer zone between areas where fertilizer is applied and the canals.

CPP4a	CARE OF THE FRUIT BAGGING To avoid damage from insects, mechanical damage, to control the correct age of the harvest, and to create a microclimate that accelerates the growth of the fruit, recently emerged fruit or those emerged within the last two weeks are covered with light density perforated polyethylene bags. The length of the bags is from 65-72 inches and the width is 32 inches. The majority of the bags used are impregnated with insecticide (clorpyrifos) at 1% concentration. Some farms do not require the use of insecticides in the bag and other only require it for part of the year. The bag with insecticide is more expensive, therefore, its use is only when the risk of damage exists. The insecticide gradually degrades with exposure to the environment. The presence of insecticide on the crop (12 weeks after bagging) is practically null. Studies conducted by the Universidad Nacional show presence of cloripyrifos in alarming quantities in packing plant residual waters without confirmed cause. Normally, the bag is tied to the racime with a plastic cord whose color indicates the age of the fruit. In cases where the bunch is very large, the bag is attached with a transparent string and a colored string tied to the lower part of the bunch to identify the age. The bags that cover the fruit are transported with the bunches to the packaging plant. In the packaging plant, the bags are gathered and compacted. The bags are stored in a warehouse and are later sent to be recycled.	APP 4aa	Intercalating bags with and without insecticides in areas with low Colaspis pressure. Careful monitoring of the farm for insect pests and damage is required.
		APP 4ab	Use a necktie system. This process introduces a strip of material impregnated with insecticide inside the bag instead of impregnating the bag itself.
		APP 4ac	Use a continuous roll of plastic instead of precut bags (Layflat). The roll is cut according to the length of the bunch. This system uses less plastic, is more convenient, and is more economical because less material is used. In addition, the plastic is packed in a box that can be carried by the worker in the field. The plastic is dispensed directly from the box. This system protects the worker from the effects of the insecticides.
		APP 4ad	Use polyethylene of higher density because this material is easier to manipulate. Polyethylene of lower density dries more rapidly and allows more air circulation around the fruit. Higher density polyethylene can be reused and recycled.
		APP 4ae	Use biodegradable bags.
		APP 4af	Use orange bags to repel insects. Verify the effect on the growth, thickening, and color of the fruit.
		APP 4ag	Use reusable bags made of mosquito netting (15 to 20 uses per bag). The fruit must be covered for only 3 weeks of its growing cycle. The cost of these bags is C0.80. While this method avoids the use of insecticide, a micro-climate is not formed within the bag.

CPP4b	CARE OF THE FRUIT PROPPING There are basically three methods of propping in use: overhead cable, bamboo and tieback. A minority of plantations use the overhead cable system because it has a sizable initial cost. However, this system has many advantages that merit evaluation and consideration (see APP4bb). There is considerable experience in using bamboo for propping. At the present time, the cost of this system is higher than the most popular system used – the tieback system. However, it also has many advantages that need evaluation (see APP4bc). The majority of the plantations use the tieback system because it requires has a low cost of application. In this system, the plants are held up by two 14-m long lengths of polypropylene twine using the support of neighboring plants. Because the twine is non-degradable and in the past was not collected, it has accumulated in the plantations degrading the soil. At the present time, most farms collect the twine from the field and stored it for recycling. This operation has a considerable cost. Recycling of the twine is partial due to the cost of transporting the twine to the recycling plants and because of deficiencies in market demand and process. The cement factories have the possibility of using the twine as fuel alleviating the problems of disposal. However, the collection and transportation of the twine to the cement factory require careful evaluation. Furthermore, this system may introduce other risks to the environment that demand evaluation (SeeAPP4bd).	APP 4ba	Tie the twine to a central pivot. This method is also known as the subaboreal system. This system avoids damage of the plants that serve as anchors. The central pivot can be any living material that stays short. It is possible to grow laurel in such a way that once the tree has reached an adequate height, it can be used as a post for an aerial support system.
		APP 4bb	Install overhead aerial support systems. This method is initially more expensive but is cheaper in the long run due to improved recovery of twine, elimination of fallen plants, ease of harvest, simplification of labor, prevention of accidents, maintenance of soil free from plastics, and improved quality of the harvested fruit.
		APP 4bc	Use vegetative material for support (bamboo, *caña brava*, and *leucana*). In the Philippines, one hectare of vegetative material is grown for support for every 10 hectares of banana.
		APP 4bd	Incinerate the polypropylene twine in the ovens of cement factories to increase the heat generated for the production of cement.
		APP 4be	Use twine made with 20 to 40% recycled resin.
		APP 4bf	Use continuous rolls of twine dispensed from a backpack and cut with an appropriate tool.
		APP 4bg	Collect the twine during harvest and send it to the packing plant with the racime.

CCP5	HARVEST The bunch is harvested manually using a machete or *chuza* to cut the plant just above the bunch. The pseudostem, commonly called *caballo*, is left on the ground. Residual organic material is chopped and spread on the plantation floor to incorporate nutrients and to prevent weed growth.	APP 5a	Remove the hands from the bunch in the field to avoid the use of cushions. The hands are transported in specially designed platforms. This system better protects the fruit and leaves the fruit stems in the field. This process allows recovery of the plastic bags during the harvest. The plastic bags are put in sacks and transported by cable to the collection center.
	When the bunch is cut from the plant, it drops to a cushion resting on a worker's shoulder so the fruit is not damaged. Sponges are woven between the fingers of the bunch to prevent damage from friction. The sponges are reused until they tear and then they are burned.	APP 5b	Use alternative methods of traction for transporting the fruit to the packing plant. The alternatives include aerial tractors, terrestrial tractors and work animals (bison, horses and mules).
	The bunch is transported to the cableway on the shoulder of the worker. The maximum carrying distance is 55 meters. The bunch is hung from the cableway on a hook attached to a set of rollers. The bunch is then transported to the packing plant on the rollers that slide along the cableway. In general, bunches are pushed along the cableway by workers.	APP 5c	Deflower the fingers in the field to eliminate microlepidoptera larvae and organic residues in the packing plant. There is a danger that a fungus could be introduced into the scar of the flower.
	The plastic bag is transported to the packing plant with the bunch. Few farms use the Rail System. A rail consists of a bar supported on the shoulders of two workers. The bunch is hung on the bar to be transported to the cableway. The use of the rail causes less damage to the fruit and is easier on the worker. The effectiveness of this process depends on the slope of the land, the number of drainage canals, and the support system. When the terrain is uneven, the operation is difficult, reducing efficiency and increasing the risk of accidents.	APP 5d	Prewash the fruit by setting up sprinklers along the cable way to lubricate and freshen the fruit during transport. This system eliminates dust and keeps the fruit fresh, improving its quality and lowering the rejection rate.

CPP6	PACKING Upon arrival at the packing plant, the plastic bags are removed and the bunches are inspected, measured, and appraised, then accepted or rejected. The percentage rejected should not exceed 3%. The flowers are then removed. The hands are detached using a curved knife. The fruit is washed, separated by quality, and cut into clusters of fingers. Depending on the age, market demand, and norms of quality, the rejection rate during selection ranges from 20-30%. The fruit that passes quality control is deposited in a flotation tank with clean, cold water, called the de-latexing tank. The fruit remains in this tank for at least 17 to 20 minutes to remove the latex that can stain the fruit. Water usage in a packing plant for a 200-hectare banana plantation exceeds 12 liters per second. Once the fruit has been washed, it is treated with Alumbre and Thiabendazole or Imazil. Some plants use special chambers to apply these products. The residuals of these products are released with the runoff water of the packing plant. The fruit is placed in boxes. The weight of the box depends on the market, with the most common weight being 18.1 kg. A plastic sheet or bag is placed inside the box. The boxes are assembled and glue is use to hold it together. Depending on the destination of the fruit, the boxes are stacked on wooden pallets. In general, there is no control on the origin of the wood and therefore, there is no guarantee that the wood is cultivated and not made from wood harvested from natural forests.	APP 6a	Use packing material that is recycled and recyclable.
		APP 6b	Redesign the tanks to reduce the volume of water used, and recycle the water through the selection tanks.
		APP 6c	Purify the water so the water used throughout the packing process can be recycled.
		APP 6d	Install filters to treat the effluent water that is contaminated with agro-chemicals.
		APP 6e	Certify the wooden pallets.
		APP 6f	Use reusable pallets, made with recycled material that is recycled once it has lost its operational capability.
		APP 6g	Use the rejected fruit as a source of organic material for making compost.
		APP 6h	Process the stem of the bunch for compost, paper, or other uses.
		APP 6I	Use the rejected fruit in industrial production of puree, starch, compost or other uses.
		APP 6j	Deposit the reject bananas that cannot be used for industrial production in trenches designed following guidelines.

CPP9	PACKING (cont'd) The fruit is transported to port in trucks. If the fruit remains in the container of the truck for more than 48 hours, it must be refrigerated.	APP 6l	Redesign maintenance areas for the aerial tractors and rollers so the floors are impermeable and spills of grease and combustibles can be contained.
	The waste generated in the packing plant is considered a point source. Some of the second quality fruit is sold in the local market as fresh fruit for human consumption. Some of this fruit is also sold as feed for cattle or pigs.	APP 6k	Use spraying chambers and modify the conventional hydraulic spray nozzles to electrostatic nozzles, considerably reducing the volume of application and avoiding spilling and loss.
	Processing plants, such as Mundimar and Gerber, consume large quantities of rejected fruit to make pure and other byproducts. Residual fruit that is not sold for alternative uses need to be disposed off. Thirty four per cent of the banana plantations have systems of trenches for burying the rejected fruit. Other producers place the rejected fruit in open piles. The stems are recovered, transported to the field and deposited on the floor of the plantation. In some cases the stems are chopped before being incorporated into the plantation. The rest of the organic waste generated by the packing plants, such as the flower and crown, is collected and managed similarly to the stems. The water from the packing plant passes through a filter to remove solids and then is discharged into canals or rivers. The material retained by the filters is incorporated into the plantation or is deposited in trenches. Very few packing plants have secondary water treatment systems or filters to remove chemicals. Prevention and containment of chemicals are practiced by some of the farms.	APP 6m	Relocate and redesign the warehouses for agro-chemicals and the plastic bags impregnated with insecticides to reduce the risk of environmental contamination and to increase the safety of the workers. Agro-chemicals should not be stored in the packing plant.

CPP7	SOCIAL AND LABOR CONDITIONS HIRING PRACTICES The majority of banana workers are employed directly by the banana company. The workers specialize in one set of tasks in the field. Each set of tasks has a wage. The wages vary according to the task that the worker carries out. The wages are paid per unit of work for the corresponding task. Very few of the tasks are paid on an hourly basis. The tasks and their wages are negotiated directly with a permanent committee of workers. The plantation is not free to make changes in these arrangements without negotiating with the permanent committee. SALARIES The incomes of banana workers are the highest in agriculture. LEGAL BENEFITS The majority of plantations contract directly with the workers, and therefore, the workers receive social benefits stipulated by the Workers' Code (vacations, thirteenth month, one-month notice and severance pay, unemployment, social security, and security from occupational hazards, etc.). Few plantations hire illegal immigrants and make contracts with third parties to avoid the costs of social benefits. This practice is not only illegal but is renounced by the majority of producers.	APP 7aa APP 7ab APP 7ac APP7 Ad APP 7ae	Introduce a system of plots assigning all the labor to a group without specialization. Implement a system of bonuses for quality and yield of work. All work should be paid based on quality and quantity. Create a bonus system that promotes attendance and prevention of accidents. Pay the severance way and services for good workers each six months as a premium for their work. Require that all contractors comply with the laws and regulations concerning workers' rights, including those clauses related to the safety guidelines and hygiene. Establish a system of control to ensure compliance

CPP7b	SOCIAL AND LABOR PRACTICES WORKING CONDITIONS HOUSING Many plantations offer hosing to their permanent workers and their families. The companies are responsible for providing maintenance, potable water, garbage collection, groundskeeping, control of insects, and maintaining order. ELECTRICITY For those employees who live in the workers' housing, the plantation provides a subsidy to help pay for electricity. WORKER TRANSPORTATION The plantations provide transportation for workers who don't live in the workers housing from nearby villages to the plantation. STUDENT TRANSPORTATION The plantation provides transportation for the children of workers living on the plantation to and from school. RECREATION The majority of banana plantations maintain sports complexes, provide uniforms, and contribute to the maintenance of teams. They also host a party for Labor Day, Mother's Day, and a party for children at Christmas. FOOD The plantations maintain caffeterias, cover electricity costs and provide equipment for refrigeration to ensure that workers have access to quality food at a reasonable price. Most farms control food quality, as well as sanitary and hygienic conditions of the living and eating areas.	APP 7ba APP 7bb APP 7bc APP 7bd APP 7be	Actively collaborate with local authorities and neighborhood development associations to improve public services in the communities surrounding the plantation. This promotes the well-being of the workers who live outside the plantation. Help workers to construct their own homes in the neighboring communities by engaging in the following activities: • Financing • Purchase and sale of land at a fair price • Facilitation of construction machinery • Design and topography. Use workers' savings and mutual aid associations to implement this plan. Help workers to construct and operate a transportation company to provide transport services for employees and students. Help to construct and maintain a common area for a cultural club. Implement a program of cultural events to present monthly at the club. Install a television room with a VCR to present weekly movies. Schedule discussions for the families of workers. Establish a system of nursery schools so women have the same opportunities as men to work in the plantation. This ensures that young children have a safe and beneficial place to stay while their parents are working.

CPP7c	WORKING CONDITIONS (Cont'd) EDUCATION Many plantations help with the education of their workers' children through the maintenance of the schools. Some offer scholarships and subsidies for education. They also contribute notebooks, pens and uniforms. TRAINING Some plantations offer periodic short, practical courses on the management of crops and fruit, and safe methods for handling tools and agro-chemicals. More farms are starting to offer classes in environmental awareness and specific training to avoid pollution, preserve resources and eliminate waste. HEALTH The majority of plantations maintain a medical clinic and a company doctor to service the workers and their families. The majority of plantations have a vehicle assigned as an ambulance. COMMUNITY CENTERS Many farms have community centers either through the Solidarity associations or as part of the negotiated package of fringe benefits offered to the workers.	APP 7bf APP 7bg APP 7bh APP 7bi	Establish a training program for the families of the workers to promote the creation of micro-enterprises that provide services to the plantations and the communities. The programs of INA can be utilized for this purpose. Designate land not used for banana production as space for family gardens for the workers. Promote religious activities within the plantation community and in neighboring communities. Designate space for religious ceremonies and for prayer group meetings. Facilitate regular visits from priests and pastors. Promote organizations that support women and families.

CPP7c	SOCIAL AND LABOR PRACTICES PRACTICES TO REDUCE WORKERS' RISKS The majority of plantations have an internal administrative unit for the management of workers' safety. Most plantations organize a workers' committee for occupational health for self-policing and to improve their programs. All plantations are required to keep statistics of workers' accidents and to report accidents to the National Institute of Safety (INS). The large companies have a system for training workers in occupational safety. Training programs for small and large companies are offered through the Environmental Commission on Bananas (CAB), the National Institute of Training (INA), and the Chamber of Agricultural Inputs. Under Costa Rican law, personal protection equipment is obligatory. The majority of the plantations comply with this requirement. The majority of plantations have special warehouses for the management of toxic substances according to the regulations set forth by the Ministry of Health. The efficiency of the production process depends to a large degree on minimizing occupational accidents. One of the most important elements is the design and the utilization of the best available tools and specialized equipment. Therefore, the majority of the plantations dedicate important resources to this task. A large number of plantations require their workers to have periodic medical exams.	APP 7ca APP 7cb APP 7cc APP 7cd APP 7ce APP 7cf	Strengthen the occupational safety unit so that occupational activities are planned on the basis of the health of the workers. The unit should provide necessary logistical support, adequate training, and the safest tools and equipment. Fund a preventative medicine unit that includes a company doctor who is responsible for the physical condition of the workers, recommends and supervises workers' hygiene, and reviews the ergonomics of the work place. Create a data bank to track occupational accidents and include an analysis of the causes to promote preventative measures. Include a labor contractual clause requiring the use of safety equipment and establish sanctions for violations of the clause. Establish an obligatory orientation course for all workers. This course should include all the occupational safety procedures and environmental protection practices that must be used in the execution of their work. Establish a unified training program through cooperation between CORBANA, CAB, agrochemical providers, assemblies, production companies, and the Ministry of Health. Issue certificates of participation to authorize and classify workers to carry out high risk jobs depending on the training certification they have.

	PRACTICES TO REDUCE WORKERS' RISKS (cont'd) Drainage Because the canals present barriers to the movement of workers through the plantation, farms install and maintain bridges in the main pathways for harvesting and applying agro-chemicals. Control of black Sigatoka Precautions are taken to avoid spraying population centers, schools, packing plants, rivers or springs. However, a large number of plantations have their packing plants and employee living quarters within the plantation. Some plantations do not respect the buffer zones for rivers, streams, and springs. The majority of plantations do not have buffer zones adjacent to roads. The new plantations have begun to correct this problem by creating buffer zones and removing living quarters from the plantation. An important group of sprayers controls the limits of spraying with GPS. The rest of the aerial spraying companies use a flag system manipulated by workers in the plantation. The flag men are exposed to the sprayed products. Protection equipment is required for these workers.	APP 7cg APP 7ch APP7 Ci APP 7cj APP 7ck APP7cl	Institute routine, programmed safety courses for pilots, warehouse employees, and mixing plant operators to improve the operation of the airport facilities. Install subsurface drainage using perforated plastic tubing to prevent occupational activities. Create protection and buffer zones of at least 100 m between the plantation, the packing plant, and employee living quarters. Bananas or other crops that require chemicals should not be grown in these zones. It is preferable that these zones are planted with species that grow to medium height to create wind barriers and to capture agro-chemical drift. Note of caution: Exercise caution with the type of edible species planted in buffer zones to prevent the possible poisoning of users. Evacuate field workers before aerial spraying and keep them out of the fields for a period of time determined by product recommendations and weather conditions (re-entry period). Establish emergency shelters for field workers who for extenuating circumstances are not able to be evacuated prior to spraying. Guide aerial spraying by using a "Flying Flagman" system or with GPS.

CPP7c	PRACTICES TO REDUCE WORKERS' RISKS (cont'd) Control of Nematodes The products used are highly toxic. Workers who apply nematicides are required to wear protective equipment to minimize risk. Workers must shower after application of nematicides. The level of cholinesterase in workers' blood is monitored. The frequency of monitoring varies depending on the product used. Some companies test workers before each cycle, others in the middle of the cycle, and others at the beginning and end of the cycle. Control of Weeds The majority of plantations use adequate protective equipment for their workers. Packing Some packing plants have special spraying chambers to apply fungicides.	APP 7cm	If a GPS system is not available, use mobile globes anchored to the floor of the plantation as indicators in place of flagmen.
		APP 7cn	Test and institute nocturnal spraying using instruments for navigation and location. This method ensures that field workers are not in the plantation and takes advantage of the better temperature and wind conditions that exist at night.
		APP 7co	Partially eliminate the use of herbicides. Control weeds manually through selection of weeds appropriate for a cover crop. Apply systemic herbicides with low environmental impact and low human toxicity (i.e., Finale) in periods when the cost of manual control is high.
		APP 7cp	Mark areas of herbicide application with labels indicating the date of application and the re-entry period.
		APP 7cq	Substitute the clorpyrifos in the plastic bags with insecticides that are less toxic to humans (cypermetrynes).
		APP 7cr	Determine the base range of cholinesterase in each worker who is in contact with clorpyrifos and monitor blood levels every three months. If a worker exhibits levels below the normal range determined by medical history, the worker's activities should be changed until the cholinesterase levels are normal.
		APP 7cs	Improve hygiene practices (frequent hand washing, prohibition of food consumption during activities involving handling of bags, prohibition of smoking).

	PRACTICES TO REDUCE WORKERS´ RISKS (cont'd)	APP 7ct	Install aerial support systems. This method is initially more expensive but is cheaper in the long run due to improved recovery of twine, elimination of fallen plants, ease of harvest, simplification of labor, prevention of accidents, maintenance of soil free of plastics and the accompanying chemicals, and improved quality of the harvested fruit.
		APP 7cu	Use alternative methods of traction for the transport of the fruit to the packing plant, such as aerial tractors, terrestrial tractors, and work animals (bison, horses, and mules).
		APP 7cv	Redesign the workplace with ergonomics in mind to minimize risks to the health of workers and to improve efficiency. The redesign of lighting is especially important.
		APP 7cw	Relocate and redesign warehouses for agro-chemicals and plastic bags to improve workers' safety and minimize the risk of environmental contamination. Agro-chemicals should not be stored in the packing plants.
		APP 7cx	Use spraying chambers in the packing plants to prevent worker exposure.
CPP7d	OTHER SOCIAL AND LABOR PRACTICES MEDICAL TREATMENT By law, each worker is insured through Costa Rica´s Social Security program (CCSS) and the National Institute of Insurance (INS). The worker and his/her family therefore have the right to receive the services provided by these institutions. A large number of plantations have a company doctor who complements the services of CCSS and INS.		

CPP7e	OTHER SOCIAL AND LABOR PRACTICES LABOR ORGANIZATIONS Solidarity associations have gained popularity. The majority of solidarity associations have different committees for workers' benefits and recreation. Some plantations without solidarity organizations have associations for savings and mutual aid. These organizations do not participate in labor negotiations with the plantation and therefore do not substitute for or exclude labor unions.		
CPP7f	OTHER SOCIAL AND LABOR PRACTICES LABOR NEGOTIATIONS Unions have lost power due to general discontent with their operations. Collective bargaining agreements have also lost popularity because they were frequently accompanied by labor strikes, many times at the expense of the workers. A few of the plantations have contracts produced through collective bargaining. The majority of workers negotiate collectively the working conditions through a permanent committee of workers and have direct arrangements with the plantations. Most contracts are negotiated without the use of labor strikes.		
CPP8	GENERAL PRACTICES NOT CONTEMPLATED IN PREVIOUS VARIABLES	APP 8	Abandon banana production for export purposes

Reference: The basis of discussions with the experts was taken the document, "Impacto de la Legislaciones Ambientales de Costa Rica y Holanda Sobre el Acceso al Mercado para Algunos Sectores Productivos Bananeros de Costa Rica y Centro América" escrito por el Ing. Luis A. Sánchez Montero. Mayo de 1996. The final product is a compendium of the contributions made by the experts using the Delphi Method. Every expert had at least two opportunities to comment on the suggestions made by the other experts and to contribute with additional information.

Table 36 - Environmental Effect Intensities (weights) Assign by the PE

Activity and Criterion Variables	Expert Number 1	3	4	5	7	8	9	11	12	13	Mean	DES. EST.	L.I.(95%)	L.S.(95%)	L.I.(90%)	L.S.(90%)	L.I.(75%)	L.S.(75%)	Mod. Mean	Coef.
Environment. Planting																				
Biodiver.	20.0%	60.0%	40.0%	30.0%	35.0%	30.0%	35.0%	20.0%	27.3%	15.0%	31.2%	12.8	6.2	56.3	10.2	52.2	16.5	45.9	29.7 %	33%
Pollution	10.0%	10.0%	25.0%	30.0%	30.0%	30.0%	30.0%	20.0%	4.5%	20.0%	21.0%	9.8	1.8	40.1	4.9	37.0	9.7	32.2	24.4 %	27%
Inputs	10.0%	10.0%	5.0%	30.0%	20.0%	20.0%	25.0%	20.0%	54.5%	60.0%	25.5%	18.4	-10.6	61.5	-4.8	55.7	4.3	46.6	17.5 %	20%
Nat. Res.	60.0%	20.0%	30.0%	10.0%	15.0%	20.0%	10.0%	40.0%	13.6%	5.0%	22.4%	16.8	-10.5	55.3	-5.2	50.0	3.1	41.7	18.2 %	20%
Drainage																				100%
Biodiver.	20.0%	60.0%	20.0%	30.0%	35.0%	30.0%	35.0%	20.0%	25.0%	15.0%	29.0%	12.9	3.8	54.2	7.8	50.2	14.2	43.8	25.6 %	29%
Pollution	10.0%	10.0%	50.0%	30.0%	30.0%	30.0%	30.0%	20.0%	5.0%	20.0%	23.5%	13.3	-2.7	49.7	1.5	45.5	8.2	38.8	20.6 %	23%
Inputs	10.0%	10.0%	30.0%	30.0%	20.0%	20.0%	25.0%	20.0%	30.0%	60.0%	25.5%	14.2	-2.4	53.4	2.1	48.9	9.1	41.9	21.7 %	25%
Nat. Res.	60.0%	20.0%	0.0%	10.0%	15.0%	20.0%	10.0%	40.0%	40.0%	5.0%	22.0%	18.9	-15.0	59.0	-9.1	53.1	0.3	43.7	20.0 %	23%
Pest Man.																				100%
Biodiver.	20.0%	30.0%	40.0%	30.0%	35.0%	25.0%	35.0%	20.0%	4.8%	15.0%	25.5%	10.7	4.5	46.5	7.9	43.1	13.2	37.8	26.3 %	27%
Pollution	10.0%	30.0%	10.0%	30.0%	30.0%	25.0%	30.0%	20.0%	33.3%	20.0%	23.8%	8.5	7.1	40.6	9.8	37.9	14.0	33.6	27.3 %	28%
Inputs	10.0%	20.0%	30.0%	30.0%	20.0%	25.0%	25.0%	20.0%	28.6%	60.0%	26.9%	13.1	1.1	52.6	5.2	48.5	11.7	42.0	24.8 %	25%
Nat. Res.	60.0%	20.0%	20.0%	10.0%	15.0%	25.0%	10.0%	40.0%	33.3%	5.0%	23.8%	16.7	-8.9	56.5	-3.6	51.3	4.6	43.0	19.8 %	20%

Table 36 - Environmental Effect Intensities (weights) Assign by the PE (Cont'd)

Fertilization.																				100%
Biodiver.	20.0%	50.0%	30.0%	30.0%	35.0%	40.0%	35.0%	20.0%	5.0%	15.0%	28.0%	13.2	2.2	53.8	6.3	49.7	12.9	43.1	28.1 %	31%
Pollution	10.0%	15.0%	40.0%	30.0%	30.0%	30.0%	30.0%	20.0%	5.0%	20.0%	23.0%	10.9	1.7	44.3	5.1	40.9	10.5	35.5	25.0 %	27%
Inputs	10.0%	15.0%	20.0%	30.0%	20.0%	20.0%	25.0%	20.0%	40.0%	60.0%	26.0%	14.5	-2.4	54.4	2.2	49.8	9.3	42.7	22.2 %	24%
Nat. Res.	60.0%	20.0%	20.0%	10.0%	15.0%	10.0%	10.0%	40.0%	50.0%	5.0%	24.0%	19.1	-13.5	61.5	-7.5	55.5	2.0	46.0	16.3 %	18%
	Expert Number																			
Activity and Criterion Variables	1	3	4	5	7	8	9	11	12	13	Mean	DES. EST.	L.I.(95%)	L.S.(95%)	L.I.(90%)	L.S.(90%)	L.I.(75%)	L.S.(75%)	Mod. Mean	Coef.
Fruit Care																				100%
Biodiver.	20.0%	40.0%	35.0%	30.0%	35.0%	30.0%	35.0%	20.0%	25.0%	0.0%	27.0%	11.6	4.3	49.7	7.9	46.1	13.7	40.3	30.0 %	31%
Pollution	10.0%	25.0%	30.0%	30.0%	30.0%	40.0%	30.0%	20.0%	25.0%	0.0%	24.0%	11.5	1.5	46.5	5.1	42.9	10.8	37.2	27.1 %	28%
Inputs	10.0%	15.0%	20.0%	30.0%	20.0%	20.0%	25.0%	20.0%	25.0%	60.0%	24.5%	13.6	-2.2	51.2	2.1	46.9	8.8	40.2	20.6 %	21%
Nat. Res.	60.0%	20.0%	15.0%	10.0%	15.0%	10.0%	10.0%	40.0%	25.0%	40.0%	24.5%	16.9	-8.6	57.6	-3.3	52.3	5.1	43.9	20.6 %	21%
Harvest																				100%
Biodiver.	20.0%	50.0%	35.0%	30.0%	35.0%	16.7%	35.0%	20.0%	15.0%	70.0%	32.7%	17.0	-0.7	66.0	4.7	60.7	13.1	52.2	28.5 %	32%
Pollution	10.0%	15.0%	30.0%	30.0%	30.0%	50.0%	30.0%	20.0%	75.0%	30.0%	32.0%	18.6	-4.4	68.4	1.4	62.6	10.6	53.4	29.4 %	33%
Inputs	10.0%	15.0%	20.0%	30.0%	20.0%	16.7%	25.0%	20.0%	5.0%	0.0%	16.2%	9.1	-1.6	33.9	1.3	31.1	5.7	26.6	18.1 %	20%
Nat. Res.	60.0%	20.0%	15.0%	10.0%	15.0%	16.7%	10.0%	40.0%	5.0%	0.0%	19.2%	17.9	-15.9	54.2	-10.3	48.6	-1.4	39.7	13.1 %	15%

Table 36 - Environmental Effect Intensities (weights) Assign by the PE (Cont'd)

Packing																				
Biodiver.	20.0%	40.0%	40.0%	30.0%	35.0%	20.0%	10.0%	20.0%	70.0%	60.0%	34.5%	18.9	-2.6	71.6	3.4	65.6	12.7	56.3	29.3 %	31%
Pollution	10.0%	20.0%	20.0%	30.0%	30.0%	30.0%	30.0%	20.0%	0.0%	10.0%	20.0%	10.5	-0.7	40.7	2.7	37.3	7.9	32.1	22.2 %	23%
Inputs	10.0%	15.0%	10.0%	30.0%	20.0%	20.0%	40.0%	20.0%	15.0%	0.0%	18.0%	11.1	-3.8	39.8	-0.3	36.3	5.2	30.8	17.5 %	18%
Nat. Res.	60.0%	25.0%	30.0%	10.0%	15.0%	30.0%	20.0%	40.0%	15.0%	30.0%	27.5%	14.6	-1.1	56.1	3.5	51.5	10.7	44.3	25.6 %	27%
Macros (*)																				100%
Biodiver.	20.0%	50.0%	NO	30.0%	35.0%	30.0%	35.0%	20.0%	25.0%	0.0%	27.2%	13.7	0.3	54.1	4.7	49.8	11.4	43.0	27.9 %	30%
Pollution	10.0%	15.0%	NO	30.0%	30.0%	30.0%	30.0%	20.0%	25.0%	40.0%	25.6%	9.2	7.6	43.5	10.5	40.6	15.0	36.1	25.7 %	28%
Inputs	10.0%	15.0%	NO	30.0%	20.0%	10.0%	25.0%	20.0%	25.0%	0.0%	17.2%	9.4	-1.2	35.6	1.8	32.7	6.4	28.0	17.9 %	19%
Nat. Res.	60.0%	20.0%	NO	10.0%	15.0%	30.0%	10.0%	40.0%	25.0%	60.0%	30.0%	19.5	-8.3	68.3	-2.1	62.1	7.5	52.5	21.4 %	23%
																				100%

(*) Macros - Aspects not covered by previous activities

Table 37 - Social Effect Intensities (weights) Assign by the PE

Activity and Criterion Variables	Expert Number 1	3	4	5	7	8	9	11	12	13	Mean	DES. EST.	L.I.(95%)	L.S.(95%)	L.I.(90%)	L.S.(90%)	L.I.(75%)	L.S.(75%)	Mod. Mean	Coef.
Social Cont. Cond.																				
Workers	50%	40%	70%	40%	75%	60%	80%	30%	70%	70%	58.5%	17.3	24.5	92.5	30.0	87.0	38.6	78.4	61.7%	62%
Health Haz	30%	25%	35%	30%	35%	20%	60%	30%	25%	60%	35.0%	13.9	7.7	62.3	12.1	57.9	19.0	51.0	28.8%	29%
W.C.C. (**)	30%	30%	25%	30%	25%	40%	10%	30%	25%	40%	28.5%	8.5	11.8	45.2	14.5	42.5	18.7	38.3	27.9%	28%
Job Security	20%	25%	25%	20%	25%	20%	20%	30%	25%	0%	21.0%	8.1	5.1	36.9	7.7	34.3	11.7	30.3	23.8%	24%
Enh. (***)	20%	20%	15%	20%	15%	20%	10%	20%	25%	0%	16.5%	7.1	2.6	30.4	4.8	28.2	8.3	24.7	17.5%	18%
Local Com.	30%	40%	20%	40%	20%	30%	10%	40%	20%	20%	27.0%	10.6	6.2	47.8	9.6	44.4	14.8	39.2	23.3%	24%
National Com.	20%	20%	10%	20%	5%	10%	10%	30%	10%	10%	14.5%	7.6	-0.4	29.4	2.0	27.0	5.7	23.3	13.8%	14%
Fringe Benefits																				
Workers	50%	40%	80%	40%	75%	60%	80%	30%	90%	60%	60.5%	20.3	20.6	100.4	27.0	94.0	37.1	83.9	60.6%	56%
Health Hazards	25%	25%	40%	30%	35%	30%	60%	30%	25%	70%	37.0%	15.7	6.3	67.7	11.2	62.8	19.0	55.0	30.0%	30%
W.C.C. (**)	25%	30%	20%	30%	25%	30%	10%	30%	25%	30%	25.5%	6.4	12.9	38.1	14.9	36.1	18.1	32.9	26.9%	27%
Job Security	25%	25%	20%	20%	25%	30%	20%	30%	25%	0%	22.0%	8.6	5.2	38.8	7.9	36.1	12.2	31.8	24.4%	25%
Enh. (***)	25%	20%	20%	20%	15%	10%	10%	20%	25%	0%	16.5%	7.8	1.1	31.9	3.6	29.4	7.5	25.5	18.3%	18%
Local Com.	30%	40%	10%	40%	20%	30%	10%	40%	5%	40%	26.5%	14.2	-1.2	54.2	3.2	49.8	10.2	42.8	34.3%	32%
National Com.	20%	20%	10%	20%	5%	10%	10%	30%	5%	0%	13.0%	9.2	-5.0	31.0	-2.1	28.1	2.4	23.6	12.5%	12%

Activity and Criterion Variables	Expert Number 1	3	4	5	7	8	9	11	12	13	Mean	DES. EST.	L.I. (95%)	L.S. (95%)	L.I. (90%)	L.S. (90%)	L.I. (75%)	L.S. (75%)	Mod. Mean	Coef.
Risk Prevention																				
Workers	50%	40%	75%	40%	75%	60%	80%	30%	90%	70%	61.0%	20.1	21.6	100.4	27.9	94.1	37.9	84.1	61.3%	62%

Table 37 - Social Effect Intensities (weights) Assign by the PE (Cont'd)

Health Hazards	25%	25%	30%	30%	35%	40%	60%	30%	75%	60%	41.0%	17.6	-34.1	75.5	12.0	70.0	20.8	61.2	37.2%	36%
W.C.C. (**)	25%	30%	30%	30%	25%	30%	10%	30%	20%	30%	26.0%	6.6	-12.6	38.9	15.2	36.8	18.4	33.6	27.8%	27%
Job Security	25%	25%	30%	20%	25%	20%	20%	30%	5%	0%	20.0%	10.0	-19.4	39.6	3.6	36.5	8.5	31.5	24.4%	23%
Enh. (***)	25%	20%	10%	20%	15%	10%	10%	20%	5%	10%	14.5%	6.4	-12.5	27.1	3.9	25.1	7.1	21.9	14.4%	14%
Local Com.	30%	40%	20%	40%	20%	20%	10%	40%	5%	30%	25.5%	12.6	-24.4	50.1	4.8	46.2	11.0	40.0	24.0%	24%
National Com.	20%	20%	5%	20%	5%	20%	10%	30%	5%	0%	13.5%	9.7	-18.9	32.6	-2.5	29.5	2.3	24.7	13.1%	13%
Others																				
Workers	50%	40%	70%	40%	75%	60%	80%	30%	90%	70%	60.5%	19.8	-38.2	99.3	28.0	93.0	37.7	83.3	60.6%	56%
Health Hazards	25%	25%	20%	30%	35%	30%	60%	30%	5%	60%	32.0%	16.9	-32.7	65.1	4.3	59.7	12.6	51.4	27.9%	29%
W.C.C. (**)	25%	30%	10%	30%	25%	30%	10%	30%	85%	30%	30.5%	20.7	-40.4	71.2	-3.6	64.6	6.6	54.4	24.4%	26%
Job Security	25%	25%	30%	20%	25%	30%	20%	30%	5%	10%	22.0%	8.6	-16.6	38.8	7.9	36.1	12.2	31.8	25.6%	27%
Enh. (***)	25%	20%	20%	20%	15%	10%	10%	20%	5%	0%	14.5%	8.0	-15.5	30.1	1.4	27.6	5.3	23.7	17.5%	18%
Local Com.	30%	40%	30%	40%	20%	30%	10%	40%	5%	30%	27.5%	12.3	-23.8	51.6	7.3	47.7	13.4	41.6	32.5%	30%
National Com	20%	20%	20%	20%	5%	10%	10%	30%	5%	0%	14.0%	9.4	-18.2	32.4	-1.4	29.4	3.2	24.8	15.0%	14%
Macros (*)																				
Workers	50%	40%	75%	40%	75%	40%	80%	30%	90%	50%	57.0%	21.0	15.9	98.1	22.5	91.5	32.9	81.1	56.3%	55%
Local Com.	30%	40%	20%	40%	20%	40%	10%	40%	5%	40%	28.5%	13.8	1.5	55.5	5.9	51.1	12.7	44.3	33.8%	33%
National Com.	20%	20%	5%	20%	5%	20%	10%	30%	5%	10%	14.5%	8.6	-2.4	31.4	0.3	28.7	4.6	24.4	12.8%	12%
																				100%

(*) Macros - Aspects not covered by previous activities

(**) Work Contracts & Conditions

(***) Enhancement

The following tables show the mean values substituted into the design matrix.

Table 38 - Mean Values Subtituted in Equation to Calculate SPI

ENVIRONMENTAL PERFORMANCE INDEXES (ENPI)											
	EXPERT NUMBER										
CPP	1	3	4	5	7	8	9	11	12	13	15	Mean
1a	0.600	0.270	0.496	0.600	0.413	0.600	0.360	0.200	0.332	0.280	0.416	0.415
1b	0.600	0.420	0.559	0.600	0.515	0.600	0.550	0.480	0.465	0.600	0.451	0.531
2a	0.600	0.200	0.515	0.600	0.430	0.600	0.200	0.280	0.209	0.200	NO	0.383
2b	0.600	0.220	0.463	0.600	0.361	0.600	0.240	0.100	0.309	0.200	0.138	0.348
2c	0.600	0.200	0.460	0.600	0.363	0.600	0.200	0.800	0.314	0.200	0.163	0.409
3	0.600	0.265	0.391	0.600	0.584	0.600	0.300	0.600	0.325	0.200	0.258	0.429
4a	0.600	0.240	0.210	0.600	0.487	0.600	0.530	0.440	0.150	0.200	0.227	0.389
4b	0.600	0.275	0.550	0.600	0.544	NO	0.460	0.440	0.150	0.400	0.380	0.440
5	0.600	0.385	0.517	0.600	0.600	0.600	0.600	0.600	0.515	0.600	NO	0.562
Mean	0.711	0.608	0.907	1.156	1.255	1.422	1.382	1.660	1.641	1.764	1.893	0.434
PACKING												
6	0.600	0.545	0.522	0.600	0.551	0.600	0.400	0.600	0.230	0.600	NO	0.525
8	NO	0.300	0.600	0.320	0.600	0.220	0.430	0.320	0.275	0.500	NO	0.357
	EXPERT NUMBER											
BAP	1	3	4	5	7	8	9	11	12	13	15	Mean
1ab	0.720	0.260	0.636	0.600	0.423	0.740	0.395	0.300	0.700	0.600	NO	0.537
1ac	0.760	0.680	0.695	0.660	0.534	1.000	0.555	0.360	0.932	0.700	NO	0.688
1ad	0.700	0.740	0.675	0.600	0.422	0.920	0.515	0.320	0.932	0.700	NO	0.652
1ae	0.640	0.590	0.798	0.600	0.492	1.000	0.660	0.280	0.918	0.800	NO	0.678
1af	0.640	0.580	0.847	0.680	0.508	1.000	0.780	0.320	0.959	0.900	NO	0.721
Mean	0.692	0.570	0.730	0.628	0.476	0.932	0.581	0.316	0.888	0.740	0.000	0.655
	EXPERT NUMBER											
BAP	1	3	4	5	7	8	9	11	12	13	15	Mean
1ba	0.600	0.600	0.593	0.680	0.521	0.860	0.700	0.480	0.550	0.800	0.601	0.635
1bb	0.720	0.640	0.692	0.640	0.543	0.900	0.800	0.320	0.615	0.800	0.739	0.674
1bc	0.760	0.360	0.654	0.620	0.542	0.520	0.830	0.520	0.580	0.600	0.638	0.602
1bd	0.700	0.780	0.702	0.680	0.570	1.000	0.895	0.800	0.670	0.800	0.827	0.766
1be	0.640	0.600	0.662	0.660	0.529	1.000	0.675	0.680	0.545	0.900	0.714	0.691
Mean	0.684	0.596	0.661	0.656	0.541	0.856	0.780	0.560	0.592	0.780	0.704	0.674
	EXPERT NUMBER											
BAP	1	3	4	5	7	8	9	11	12	13	15	Mean
2ab	0.900	0.600	0.549	0.780	0.428	0.650	0.360	0.680	0.305	0.700	NO	0.595
2ae	0.760	0.230	0.540	0.660	0.397	0.600	0.525	0.560	0.519	0.700	0.754	0.568
2af	0.640	0.450	0.676	0.720	0.435	1.000	0.560	0.760	0.652	0.800	0.869	0.687
2ag	0.760	0.430	0.686	0.660	0.448	1.000	0.780	0.760	0.686	0.800	0.869	0.716
2ah	0.760	0.640	0.615	0.660	0.385	0.900	0.660	0.760	0.681	0.800	0.855	0.701
Mean	0.764	0.470	0.613	0.696	0.419	0.830	0.577	0.704	0.569	0.760	0.837	0.654

Table 38 (Cont'd) – Mean Values Subtituted in Equation to Calculate SPI

	EXPERT NUMBER										
BAP	1	3	4	5	7	8	9	11	12	13	15	Mean
2bb	0.980	0.800	0.578	0.660	0.510	0.900	0.815	0.720	0.724	0.800	0.991	0.771
2be	0.800	0.300	0.604	0.660	0.361	0.600	0.685	0.720	0.600	0.800	0.826	0.632
2bf	0.820	0.660	0.608	0.780	0.483	0.700	0.845	0.740	0.662	0.800	0.931	0.730
Mean	0.867	0.587	0.597	0.700	0.451	0.733	0.782	0.727	0.662	0.800	0.916	0.711
ENVIRONMENTAL PERFORMANCE INDEXES (ENPI)												
	EXPERT NUMBER											
BAP	1	3	4	5	7	8	9	11	12	13	15	Mean
2ca	0.980	0.600	0.560	0.680	0.723	0.900	0.660	0.720	0.662	0.800	0.867	0.741
2cb	0.980	0.800	0.647	0.660	0.713	0.850	0.840	0.760	0.724	0.600	0.827	0.764
2cc	0.940	0.740	0.576	0.540	0.661	0.800	0.945	0.680	0.795	0.900	0.500	0.734
2ce	0.700	0.400	0.526	0.660	0.466	0.600	0.655	0.600	0.495	0.600	0.580	0.571
Mean	0.900	0.635	0.577	0.635	0.641	0.788	0.775	0.69	0.669	0.725	0.694	0.703
	EXPERT NUMBER											
BAP	1	3	4	5	7	8	9	11	12	13	15	Mean
3a	0.760	0.315	0.428	0.660	0.606	0.600	0.655	0.600	0.495	0.800	0.700	0.602
3b	0.740	0.350	0.459	0.660	0.610	0.640	0.735	0.600	0.875	0.800	0.700	0.652
3c	0.620	0.385	0.501	0.720	0.597	0.600	0.710	0.600	0.915	0.800	0.799	0.659
3d	0.780	0.415	0.560	0.620	0.602	0.600	0.775	0.600	0.955	0.800	0.799	0.682
3e	0.940	0.600	0.613	0.740	0.680	0.880	0.845	0.720	0.975	0.800	1.000	0.799
3f	0.800	0.280	0.542	0.540	0.585	0.700	0.625	0.600	0.655	0.800	0.702	0.621
3g	1.000	0.400	0.604	0.800	0.591	1.000	0.720	0.720	0.715	0.800	NO	0.735
3j	1.000	0.800	0.656	0.860	0.654	0.960	0.880	0.680	0.945	0.800	0.900	0.830
3k	0.940	0.600	0.690	0.620	0.603	1.000	0.910	0.760	0.980	0.800	0.600	0.773
Mean	0.842	0.461	0.561	0.691	0.614	0.776	0.762	0.653	0.834	0.800	0.775	0.706
	EXPERT NUMBER											
BAP	1	3	4	5	7	8	9	11	12	13	15	Mean
4aa	0.780	0.465	0.500	0.780	0.513	0.520	0.675	0.640	0.375	0.200	0.500	0.541
4ab	0.800	0.500	0.540	0.740	0.499	0.620	0.720	0.640	0.400	0.600	0.500	0.596
4ac	0.660	0.340	0.700	0.620	0.503	0.520	0.710	0.640	0.450	0.600	0.797	0.595
4ad	0.580	0.315	0.500	0.540	0.495	0.580	0.700	0.640	0.500	0.600	0.800	0.568
Mean	0.705	0.405	0.56	0.67	0.503	0.56	0.701	0.64	0.431	0.5	0.649	0.575
	EXPERT NUMBER											
BAP	1	3	4	5	7	8	9	11	12	13	15	Mean
4bb	0.720	0.430	0.590	0.720	0.547	NO	0.730	0.680	0.275	0.500	0.477	0.567
4be	0.660	0.500	0.580	0.660	0.564	NO	0.730	0.600	0.450	0.600	0.631	0.598
4bf	0.620	0.360	0.690	0.720	0.557	NO	0.665	0.600	0.225	0.600	0.451	0.549
4bg	0.660	0.585	0.570	0.840	0.549	NO	0.770	0.720	0.250	0.600	0.768	0.631
Mean	0.665	0.469	0.608	0.735	0.554	0.000	0.724	0.650	0.300	0.575	0.582	0.586

Table 38 (Cont'd) - Mean Values Subtituted in Equation to Calculate SPI

	EXPERT NUMBER											
BAP	1	3	4	5	7	8	9	11	12	13	15	Mean
5a	0.600	0.600	0.555	0.600	0.600	0.800	0.690	0.520	0.655	0.700	NO	0.632
5c	0.620	0.465	0.598	0.600	0.600	0.833	0.665	0.520	0.705	0.800	NO	0.641
5d	0.640	0.335	0.543	0.540	0.595	0.700	0.600	0.560	0.630	0.800	NO	0.594
Mean	0.620	0.467	0.565	0.580	0.598	0.778	0.652	0.533	0.663	0.767	0.000	0.622

ENVIRONMENTAL PERFORMANCE INDEXES (ENPI)

	EXPERT NUMBER											
BAP	1	3	4	5	7	8	9	11	12	13	15	Mean
6a	0.620	0.600	0.559	0.660	0.562	0.800	0.660	0.680	0.840	0.800	NO	0.678
6b	0.860	0.600	0.668	0.620	0.582	0.860	0.780	0.760	0.885	0.800	NO	0.742
6c	0.860	0.770	0.662	0.640	0.582	0.920	0.750	0.720	0.845	0.800	NO	0.755
6d	0.840	0.770	0.692	0.700	0.595	0.860	0.850	0.720	0.660	0.800	NO	0.749
6e	0.720	0.650	0.617	0.600	0.571	0.800	0.810	0.600	0.865	0.800	NO	0.703
6g	0.940	0.770	0.622	0.820	0.579	0.920	0.870	0.720	0.885	0.800	NO	0.793
6h	0.940	0.770	0.589	0.700	0.577	0.920	0.850	0.720	0.885	0.800	NO	0.775
6k	0.920	0.675	0.630	0.660	0.568	0.880	0.670	0.760	0.870	0.600	NO	0.723
6l	0.780	0.640	0.628	0.660	0.599	0.600	0.830	0.720	0.885	0.800	NO	0.714
6m	0.740	0.690	0.619	0.600	0.562	0.600	0.720	0.760	0.860	0.800	NO	0.695
Mean	0.822	0.694	0.629	0.666	0.578	0.816	0.779	0.716	0.848	0.780	0.000	0.733

SOCIAL PERFORMANCE INDEXES (SOPI)

	EXPERT NUMBER										
CPP	1	3	4	5	7	8	9	11	12	13	Mean
7a	0.600	0.286	0.611	0.600	0.498	0.600	0.508	0.600	0.553	0.600	0.546
7b	0.600	0.424	0.607	0.600	0.597	0.600	0.676	0.600	0.477	0.600	0.578
7c	0.600	0.488	0.629	0.600	0.466	0.600	0.676	0.600	0.590	0.600	0.585
7d	0.600	0.490	0.619	0.928	0.495	1.000	0.600	1.000	0.600	0.600	0.693
7e	0.600	0.600	0.629	0.776	0.612	0.952	0.712	0.740	0.772	0.400	0.679
7f	0.600	0.600	0.622	0.640	0.604	0.952	0.720	0.780	0.409	0.600	0.653
8	0.600	0.500	0.600	0.600	0.569	0.960	0.800	1.000	0.600	0.600	0.683

	EXPERT NUMBER										
BAP	1	3	4	5	7	8	9	11	12	13	Mean
7ab	0.680	0.474	0.636	0.736	0.576	0.720	0.684	0.642	0.570	0.800	0.652
7ac	0.650	0.522	0.624	0.616	0.575	0.756	0.740	0.660	0.623	0.700	0.647
7ad	0.820	0.522	0.638	0.784	0.554	0.648	0.600	0.660	0.623	0.600	0.645
7ae	0.980	0.600	0.619	0.880	NO	0.648	0.672	0.800	0.740	0.800	0.749
Mean	0.783	0.530	0.629	0.754	0.568	0.693	0.674	0.691	0.639	0.725	0.673

	EXPERT NUMBER										
BAP	1	3	4	5	7	8	9	11	12	13	Mean
7ba	0.710	0.600	0.644	0.928	0.572	0.804	0.752	0.800	0.578	0.800	0.719
7bb	0.850	0.600	0.638	1.000	0.571	0.988	0.752	0.660	0.678	0.900	0.764
7bc	0.795	0.600	0.617	0.736	0.576	0.880	0.648	0.740	0.678	0.700	0.697
7bd	0.735	0.600	0.603	0.720	0.567	0.856	0.652	0.660	0.728	0.700	0.682

Table 38 (Cont'd) - Mean Values Subtituted in Equation to Calculate SPI

7be	0.870	0.640	0.636	0.920	0.594	0.952	0.668	0.580	0.723	0.800	0.738

7bf	0.710	0.600	0.632	0.720	0.580	0.856	0.748	0.520	0.705	0.800	0.687
7bg	0.675	0.580	0.595	0.704	0.575	0.964	0.618	0.520	0.638	0.800	0.667
7bh	0.700	0.648	0.638	0.720	0.558	0.764	0.642	0.600	0.728	0.800	0.680
7bi	0.810	0.800	0.639	0.760	0.580	0.764	0.642	0.660	0.745	0.800	0.720
Mean	0.762	0.630	0.627	0.801	0.575	0.870	0.680	0.638	0.689	0.789	0.706
SOCIAL PERFORMANCE INDEXES (SOPI)										
	EXPERT NUMBER									
BAP	1	3	4	5	7	8	9	11	12	13	Mean
7ca	0.810	0.627	0.632	0.824	0.533	0.936	0.732	0.660	0.706	0.700	0.716
7cb	0.935	0.636	0.63	0.888	0.547	0.976	0.788	0.940	0.788	0.800	0.793
7cc	0.625	0.600	0.622	0.600	0.500	0.904	0.788	0.800	0.776	0.800	0.702
7cd	0.675	0.600	0.626	0.808	0.517	0.592	0.868	0.520	0.843	0.900	0.695
7ce	0.725	0.700	0.639	0.648	0.552	0.896	0.884	0.660	0.963	0.800	0.747
7cf	0.785	0.600	0.619	0.824	0.583	0.812	0.884	0.740	0.993	0.800	0.764
7cg	0.725	0.600	0.634	0.728	0.535	0.776	0.866	0.520	0.993	0.800	0.718
7ci	0.735	0.700	0.640	0.648	0.519	0.840	0.884	0.636	0.781	0.800	0.718
7cl	0.725	0.700	0.614	0.848	0.520	0.912	0.884	0.796	0.778	0.800	0.758
7cm	0.760	0.700	0.593	0.664	NO	0.912	0.884	0.648	0.778	0.800	0.749
7cn	0.640	0.300	0.664	0.544	0.572	0.900	0.904	0.660	0.967	0.600	0.675
7co	0.725	0.600	0.622	0.768	0.548	0.900	0.730	0.740	0.951	0.800	0.738
7cq	0.700	0.500	0.624	0.784	0.576	0.928	0.770	0.648	0.933	0.800	0.726
7cr	0.835	0.700	0.613	0.712	0.515	1.000	0.778	0.740	0.933	0.800	0.763
7ct	0.625	0.600	0.606	0.728	0.508	0.840	0.730	0.600	0.798	0.800	0.684
7cv	0.700	0.600	0.595	0.696	0.517	0.840	0.828	0.600	0.898	0.800	0.707
7cw	0.700	0.600	0.617	0.648	0.495	0.848	0.860	0.600	0.965	0.800	0.713
Mean	0.731	0.61	0.623	0.727	0.534	0.871	0.827	0.677	0.873	0.788	0.727
ECONOMIC PERFORMANCE INDEXES (ECPI) FIELD PRACTICES										
	EXPERT NUMBER									
CPP	1	3	4	5	7	8	9	11	12	13	Av.
1a	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
1b	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
2a	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
2b	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
2c	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
3	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
4a	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
4b	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
5	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
PACKING										
6	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
HIERING PRACTICES										
7a	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
FRINGE BENEFITS										
7b	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600

Table 38 (Cont'd) - Mean Values Subtituted in Equation to Calculate SPI

RISK PREVENTION										
7c	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
OTHERS										
7d	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
7e	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
7f	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	NO	0.600	0.600
MACROS										
8	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600

ECONOMIC PERFORMANCE INDEXES (ECPI) FIELD PRACTICES											
	EXPERT NUMBER										
BAP	1	3	4	5	7	8	9	11	12	13	Mean
1ab	0.649	0.682	0.537	0.524	0.583	0.552	0.634	0.645	0.793	0.600	0.620
1ac	0.328	0.687	0.728	0.328	0.574	0.506	0.743	0.328	0.786	0.500	0.551
1ad	0.227	0.700	0.650	0.160	0.578	0.334	0.662	0.187	0.785	0.600	0.488
1ae	0.206	0.473	0.657	0.342	0.583	0.598	0.503	0.305	0.792	0.600	0.506
1af	0.502	0.686	0.654	0.675	0.584	NO	0.491	0.502	0.563	0.600	0.584
1ba	0.358	0.501	0.680	0.428	0.602	0.423	0.729	0.183	0.590	0.600	0.509
1bb	0.792	0.501	0.707	0.966	0.604	0.429	0.738	0.327	0.510	0.400	0.597
1bc	0.676	0.599	0.712	0.673	0.590	0.356	0.769	0.664	0.539	0.500	0.608
1bd	0.273	0.406	0.657	0.732	0.613	0.694	0.615	0.732	0.537	0.600	0.586
1be	0.626	0.514	0.699	0.696	0.590	NO	0.554	0.626	0.534	0.600	0.604
2ab	0.405	0.553	0.661	0.438	0.568	0.676	0.608	0.405	0.775	0.600	0.569
2ae	0.684	0.466	0.624	0.682	0.546	0.515	0.630	0.692	0.588	0.400	0.583
2af	0.540	0.502	0.706	0.475	0.578	0.630	0.605	0.716	0.564	0.600	0.592
2ag	0.415	0.503	0.742	0.470	0.606	0.630	0.643	0.739	0.566	0.600	0.591
2ah	0.876	0.504	0.598	0.675	0.613	0.529	0.643	0.876	0.603	0.600	0.652
2bb	1.000	0.490	0.707	0.752	0.588	0.363	0.720	0.899	0.689	0.500	0.671
2be	0.802	0.601	0.775	0.777	0.571	0.538	0.753	0.775	0.701	0.500	0.679
2bf	0.639	0.506	0.567	0.732	0.597	0.529	0.654	0.639	0.568	0.600	0.603
2ca	0.709	0.555	0.661	0.635	0.635	0.533	0.654	0.774	0.670	0.600	0.643
2cb	0.709	0.590	0.720	0.635	0.633	0.541	0.705	0.803	0.670	0.600	0.661
2cc	0.606	0.568	0.654	0.532	0.643	0.300	0.705	0.704	0.669	0.500	0.588
2ce	0.775	0.661	0.664	0.775	0.598	0.491	0.652	0.600	0.599	0.400	0.622
3a	0.478	0.638	0.589	0.478	0.582	0.701	0.670	0.577	0.690	0.600	0.600
3b	0.607	0.600	0.626	0.605	0.588	0.628	0.720	0.605	0.720	0.600	0.630
3c	0.676	0.552	0.616	0.478	0.600	0.638	0.619	0.577	0.688	0.600	0.604
3d	0.676	0.502	0.616	0.478	0.595	0.628	0.720	0.577	0.686	0.600	0.608
3e	0.309	0.575	0.700	0.307	0.584	0.366	0.708	0.605	0.618	0.500	0.527
3f	0.499	0.538	0.606	0.501	0.590	0.602	0.652	0.399	0.699	0.500	0.559
3g	0.309	0.538	0.646	0.307	0.600	0.538	0.652	0.605	0.645	0.500	0.534
3j	0.607	0.506	0.682	0.615	0.602	0.404	0.665	0.600	0.570	0.600	0.585
3k	0.402	0.603	0.601	0.652	0.602	0.630	0.714	0.536	0.489	0.600	0.583
4aa	0.803	0.651	0.639	0.701	0.610	0.602	0.776	0.701	0.701	0.500	0.668
4ab	0.640	0.514	0.591	0.638	0.608	0.529	0.709	0.638	0.750	0.500	0.612
4ac	0.431	0.650	0.643	0.439	0.609	0.701	0.652	0.638	0.701	0.600	0.606
4ad	0.501	0.712	0.558	0.501	0.609	0.601	0.651	0.501	0.701	0.600	0.594
4bb	0.606	0.502	0.580	0.821	0.574	0.536	0.689	0.647	0.596	0.500	0.605
4be	0.605	0.601	0.622	0.703	0.576	0.404	0.600	0.701	0.602	0.600	0.601

Table 38 (Cont'd) - Mean Values Subtituted in Equation to Calculate SPI

4bf	0.605	0.650	0.600	0.640	0.000	0.512	0.652	0.602	0.652	0.600	0.551
4bg	0.505	0.554	0.657	0.452	0.601	0.526	0.579	0.505	0.570	0.600	0.555
5a	0.432	0.638	0.694	0.449	0.591	0.439	0.656	0.440	0.568	0.600	0.551
5c	0.208	0.564	0.698	0.427	0.623	0.538	0.557	0.440	0.568	0.600	0.522
5d	0.511	0.537	0.621	0.796	0.592	NO	0.557	0.511	0.598	0.600	0.591
Mean	0.553	0.568	0.651	0.574	0.581	0.493	0.657	0.584	0.641	0.560	0.590

ECONOMIC PERFORMANCE INDEXES (ECPI)
PACKING

BAP	EXPERT NUMBER									
	1	3	4	5	7	8	9	11	12	13	Mean
6a	0.679	0.540	0.603	0.822	0.611	0.590	0.600	0.778	0.701	0.600	0.652
6b	0.701	0.661	0.655	0.699	0.608	0.701	0.599	0.680	0.700	0.600	0.660
6c	0.502	0.661	0.623	0.500	0.599	0.699	0.601	0.680	0.700	0.500	0.607
6d	0.502	0.545	0.656	0.500	0.593	0.437	0.601	0.793	0.699	0.600	0.593
6e	0.505	0.589	0.647	0.600	0.583	0.592	0.602	0.600	0.551	0.600	0.587
6g	0.540	0.629	0.659	0.540	0.587	0.410	0.621	0.638	0.619	0.600	0.584
6h	0.505	0.576	0.680	0.407	0.590	0.628	0.570	0.603	0.619	0.600	0.578
6k	0.528	0.589	0.602	0.449	0.593	0.600	0.601	0.515	0.650	0.600	0.573
6l	0.801	0.588	0.768	0.798	0.607	0.500	0.650	0.676	0.549	0.400	0.634
6m	0.798	0.514	0.695	0.531	0.592	0.598	0.602	0.725	0.596	0.500	0.615
Mean	0.606	0.589	0.659	0.585	0.596	0.576	0.605	0.669	0.638	0.560	0.608

ECONOMIC PERFORMANCE INDEXES (ECPI)
HIERING PRACTICES

BAP	EXPERT NUMBER									
	1	3	4	5	7	8	9	11	12	13	Mean
7ab	0.430	0.600	0.663	0.430	0.618	0.536	0.652	0.513	0.664	0.600	0.571
7ac	0.430	0.600	0.660	0.440	0.618	0.536	0.620	0.513	0.695	0.600	0.571
7ad	0.577	0.612	0.658	0.575	0.558	0.536	0.600	0.575	0.632	0.500	0.582
7ae	0.501	0.595	0.611	0.501	0.000	0.536	0.600	0.501	0.600	0.600	0.505
Mean	0.485	0.602	0.648	0.487	0.449	0.536	0.618	0.526	0.648	0.575	0.557

ECONOMIC PERFORMANCE INDEXES (ECPI)
FRINGE BENEFITS

BAP	EXPERT NUMBER									
	1	3	4	5	7	8	9	11	12	13	Mean
7ba	0.577	0.588	0.636	0.577	0.589	0.536	0.559	0.577	0.602	0.600	0.584
7bb	0.577	0.578	0.683	0.577	0.591	0.565	0.559	0.577	0.602	0.500	0.581
7bc	0.577	0.577	0.641	0.577	0.593	0.498	0.592	0.577	0.568	0.600	0.580
7bd	0.577	0.576	0.640	0.577	0.594	0.598	0.597	0.577	0.567	0.500	0.580
7be	0.577	0.539	0.729	0.577	0.580	0.534	0.579	0.577	0.598	0.500	0.579
7bf	0.577	0.552	0.739	0.577	0.590	0.435	0.589	0.577	0.568	0.600	0.580
7bg	0.526	0.537	0.651	0.579	0.591	0.598	0.588	0.579	0.631	0.600	0.588
7bh	0.577	0.584	0.694	0.577	0.594	0.600	0.589	0.577	0.599	0.600	0.599
7bi	0.577	0.584	0.673	0.577	0.594	0.600	0.589	0.577	NO	0.600	0.597
Mean	0.571	0.568	0.676	0.577	0.591	0.552	0.582	0.577	0.592	0.567	0.585

Table 38 (Cont'd) - Mean Values Subtituted in Equation to Calculate SPI

ECONOMIC PERFORMANCE INDEXES (ECPI) RISK PREVENTION										
	EXPERT NUMBER									
BAP	1	3	4	5	7	8	9	11	12	13	Mean
7ca	0.575	0.583	0.703	0.575	0.580	0.581	0.577	0.573	0.568	0.600	0.592
7cb	0.550	0.403	0.819	0.550	0.585	0.478	0.587	0.573	0.587	0.500	0.563
7cc	0.575	0.501	0.698	0.575	0.575	0.600	0.589	0.575	0.600	0.600	0.589
7cd	0.600	0.600	0.600	0.600	0.590	0.527	0.600	0.600	0.600	0.600	0.592
7ce	0.407	0.584	0.719	0.480	0.585	0.600	0.590	0.575	0.589	0.600	0.573
7cf	0.506	0.502	0.721	0.508	0.585	0.579	0.590	0.501	0.612	0.600	0.570
7cg	0.501	0.454	0.705	0.603	0.590	0.600	0.590	0.501	0.595	0.500	0.564
7ci	0.407	0.405	0.711	0.503	0.595	0.505	0.553	0.601	0.597	0.600	0.548
7cl	0.747	0.557	0.640	0.803	0.590	0.597	0.585	0.809	0.600	0.400	0.633
7cm	0.719	0.552	0.610	0.819	0.596	0.597	0.587	0.819	0.567	0.500	0.637
7cn	0.830	0.541	0.635	0.830	0.608	0.587	0.605	0.764	0.566	0.400	0.637
7co	0.658	0.592	0.570	0.658	0.582	0.543	0.557	0.703	0.564	0.500	0.593
7cq	0.602	0.601	0.680	0.602	0.619	0.505	0.600	0.602	0.600	0.600	0.601
7cr	0.579	0.535	0.710	0.571	0.596	0.581	0.577	0.569	0.589	0.600	0.591
7ct	0.725	0.503	0.645	0.626	0.598	0.676	0.586	0.624	0.546	0.400	0.593
7cv	0.480	0.600	0.703	0.630	0.610	0.480	0.574	0.638	0.599	0.600	0.591
7cw	0.600	0.454	0.681	0.600	0.597	0.491	0.584	0.697	0.597	0.500	0.580
Mean	0.592	0.527	0.679	0.620	0.593	0.560	0.584	0.631	0.587	0.535	0.591

BIBLIOGRAPHY

BIBLIOGRAPHY

Allenby, B. 1996. A Design for Environment Methodology for Evaluating Materials. Total Quality Environmental Management. New York, N. Y.: John Wiley & Sons, Inc. Volume 5, Number 4. Summer 1996.

Altieri, M. 1983. Agroecology: the Scientific Basis of Alternative Agriculture. Berkeley, California: Division of Biological Control, University of California.

Altieri, M. 1987. Agroecology: The Scientific Basis of Alternative Agriculture. Boulder: Westview Press.

ANAPROBAN. 1995. Internal document.

Axinn, G. 1993 Class Notes. RD 876 International Community and Organization Development, A Comparative Perspective, Oct. 19,1993.

Axinn, G. 1988. International Technical Interventions in Agriculture and Rural Development: Some Basic Trends, Issues and Questions. Agriculture and Human Values. Winter-Spring, pp. 6-15.

Babbie, E. 1983. The Practice of Social Research. Third Edition. Belmont, California: Wadsworth, Inc.

Bailey, P. and Soyca, P. 1996. Environmental Accounting- Making it Work for Your Company. Total Quality Environmental Management. New York, N. Y.: John Wiley & Sons, Inc. Volume 5, Number 4. Summer 1996.

Banco Central de Costa Rica. 1993. Statistics.

Beus, C. and Dunlap, R. 1990. Conventional versus Alternative Agriculture: The Paradigmatic Roots of the Debate. Rural Sociology 55(4). pp. 590-616.

Boillot, J. 1997. The Drift Coalition. Agricultural Aviation. May/June pp. 20-21.

Bourgois, P. I. 1989. Ethnicity at Work: Divided Labor on a Central American Banana Plantation. Baltimore: Johns Hopkins University Press.

Brown, H. 1996. Pragmatic Ethics and the New Consultant. Total Quality Environmental Management. New York, N. Y.: John Wiley & Sons, Inc. Volume 5, Number 4. Summer 1996. pp. 1 6.

Brown, Lester R. 1993. "The New Era Unfolds" State of the World 1993. Ed. Starke, Linda. New York: W. W. Norton & Company.

Casey Gaspar, J. 1979. Limón, 1880-1940: Un Estudio de la Industria Bananera en Costa Rica. San Jose, Costa Rica: Editorial Costa Rica.

Castillo, L. August 21, 1997. Presencia de Agroquimicos en Canales de Drenaje y Riesgo Ambiental. Simposio Internacional Sobre Riego y Drenaje en Banano. EARTH, Costa Rica: Programa de Plaguicidas: Desarrollo, Salud y Ambiente, Universidad Nacional, Heredia, Costa Rica. (Oral presentation and writtern unpublished material).

Churchman, C. West. 1968. The systems approach. New York: Dell Publishing Co., Inc.

Colby, M. 1990. Environmental Management in Development: The Evolution of Paradigms. World Bank Discussion Paper.

Comisión Ambiental Bananera (CAB). 1997. Analisis y Comentarios del Sector Bananero al "Diagnostico Ambiental de la Actividad Bananera en Sarapiquí, Tortuguero y Talamanca en Costa Rica 1990-1992". San José, Costa Rica: Corporación Bananera Nacional.

Committee on Sustainable Agriculture and the Environment in the Humid Tropics (CSA). 1993. Sustainable Agriculture and the Environment in the Humid Tropics. National Research Council. Washington DC: National Academy Press.

Cunnigham, W. P. and Saigo, B. 1990. Environmental Science. Dubuque, Iowa: Wm. C. Brown Publishers.

Daly, H. 1991. Steady-state Economics. Washington, D. C.: Island Press.

Daly, H. and Cobb, J. 1989. For the Common Good. Becom Press.

del Camino, R. y Muller, S. 1993, Sostenibilidad de la Agricultura y los Recursos Naturales: Base para Establecer Indicadores. San José, Costa Rica: Deutsche Geselischaft fur Technische Zusammenarbeit (GTZ) y Instituto Inteamericano de Cooperación para la Agricultura (IICA).

Deutsche Gesellschaft Fur Technis Che Zusammenarbeit (GTZ) and Instituto Interamericano de Cooperación para la Agricultura (IICA). 1996. Evaluación y Seguimiento del Impacto Ambietal en Proyectos de Inversión para el Desarrollo Agrícola Rural: Una Aproximación al Tema. San José, Costa Rica.

Easterbrook, G. 1995. A Moment on the Earth: The Coming Age of Environmental Optimism. New York, New York: Penguin Books.

Edmunds, S. and Letery, J. 1975 Ordenamiento y Gestión del Medio Ambiente. Translated to Spanish by Hernández, J. Instituto de Estuidos Superiores de Administración Local, Madrid. New York: McGraw Hill Book Company.

Edwards, C.A., Grove, T.L., Harwood, R.R., and Pierce Colfer, C.J. 1993. The role of agroecology and integrated farming systems in agricultural sustainability. Agricultural Ecosystems Environment 46: 99-121.

Escuela de Agricultura de la Region Tropical Humeda. 1991. Seminario—Problematica ambiental relacionada con el cultivo de banano en Costa Rica—Notes (Hernandez) regarding comments made by participants during discussion session. San Jose, Costa Rica.

Expert Choice, Inc. 1995. Decision Support Software. Users Manual. ECPro for Windows. Pittsburgh, Pennsylbania: Expert Choice Inc.

Fiksel, J. 1996. Achieving Eco-Efficiency Through Design for Environment. Total Quality Environmental Management. New York, N. Y.: John Wiley & Sons, Inc. Volume 5, Number 4. Summer 1996.

Flevin, C. and Young, J. 1993. "Shaping the Next Industrial Revolution". State of the World 1993. Ed. Starke, Linda. New York: W. W. Norton & Company.

Foro Industrial. 1994 (November 20). La Nacion. National Chamber of Industry. San Jose, Costa Rica.

Gobierno de Costa Rica and Deutsche Gesellschaft Fur Technis Che Zusammenarbeit (GTZ). 1991. Plan nacional de manejo de desechos de Costa Rica. Informe Final. PN 84.2084.6-30.106. San Jose, Costa Rica, p. 10.

Hall, C. 1990. Sanctioning Resource Depletion: Economic Development and Neo-Classical Economics. The Ecologist, V20, Nº 3 May/June 1990.

Hall, C., Cleveland, C., and Kaufmann, R. 1992. Energy and Resource Quality: The ecology of the Economic Process. Niwot, Colorado: John Wiley & Sons.

Hall, C.A.S. and Day, J.W. Jr. 1977. Ecosystem models in theory and practice: An introduction with case histories. New York: John Wiley & Sons, p. 6-36.

Hernández, C. and Witter, S. G. 1996. Evaluating and managing the Environmental Impact of Banana Production in Costa Rica: A Systems Approach. Journal of the Human Environment-AMBIO, Vol. 25(3). pp.171-178.

Hilje, I., Castillo, J., Thrupp, L., and Wesseling, I. 1992. El uso de los Plaguicidas en Costa Rica. San Jose, Costa Rica: EUNEO, Heliconia.

Huss, R. 1994. Economic Justice for Sustainable Health. In DEVELOPMENT - The Journal of the Society for International Development. 1994: 3, pp.14-23.

Instituto Interamericano de Cooperación para la Agricultura (IICA). 1991. Bases para una Agenda de Trabajo para el Desarrollo Agropecuario Sostenible. San José, Costa Rica: IICA

Janzen, D.H. 1983. Costa Rican Natural History. Chicago: University of Chicago Press.

Johannson. 1996. Total Quality Environmental Management. New York, N. Y.: John Wiley & Sons, Inc. Volume 5, Number 4. Summer 1996.

Kachigan, K. 1986. Statistical Analysis: An Interdisciplinary Introduction to and Multivariate Methods. New York, N. Y.: Radius Press.

Kepner, C.D. 1935. The Banana Empire: A Case Study of Economic Imperialism. New York: Vanguard Press.

Kohlman, B. 1997. Notes from Applied Ecology Course. Escuela de Agricultura de la Región Tropical Húmeda. Guácimo, Limón, Costa Rica

Langmore, J. 1994. Policy Reform and Poverty Reduction: are the two compatible?. In DEVELOPMENT - The Journal of the Society for International Development. 1994: 3, pp. 53-56.

Lauer, W. 1989. Climate and Weather. In: Ecosystems of the World 14B: Topical Rain Forest Ecosystems. Lieth, H. and Werger, M. J. A. (eds). Amsterdam: Elseviser Science Publishers. pp. 7-49.

López, M. 1992. Método de la Matriz de Leopold. Curso Regional sobre Formulación y Evaluación de Proyectos de Desarrollo con Envasis en Evaluación de Impacto Ambiental. San José. Costa rica. R:R., ICAP, ASDI, Contraloría General de la Repüblica.

Mata, A. y Quevedo, F. 1990. Diccionario Didáctico de Ecología. San José, Costa Rica: Universidad de Costa Rica.

McCann, T. P. 1976. An American Company: The Tragedy of United Fruit. New York: Crown Publishers.

McKenry, M. W. 1991. The Nature, Mode of Action, and Biological Activity of Nematicides. In: CRC Handbook of Pest Management. Pimentel, D. (ed). Boca Raton, FL:CRC Press. pp. 461-496.

Meadows, D., Meadows, D., and Randers, J. 1992. Beyond The Limits. Post Mills, Vermont: Chelsea Green Publishing Company.

Metcalf, K., Williams, P., Minter, J. R., and Hobson, C. 1996. Environmental Performance Indicators for Enhancing Environmental Management. Total quality Environmental Management. New York, N. Y.: John Wiley & Sons, Inc. Volume 5, Number 4. Summer 1996. pp. 7-11.

Miller, G. 1956. "The Magical Number Seven Plus or Minus Two: Some Limits on Our Capacity for Processing Information." Psychological Review 13:81-97.

Ministerio de Ciencia y Tecnología de la República de Costa Rica (MICIT). 1995. Oportunidades para la Aplicación de Tecnolgía Limpias en Costa Rica.

Ministerio de Recursos Naturales, Energia y Minas (MIRENEM). 1992. Estrategia de conservacion para el desarrollo sostenible de llanuras de tortuguero (Unpublished). San Jose, Costa Rica.

Mitsch, W. 1993. Ecological Engineering: A cooperative Role with the Planetary Life-Support System. American Chemical Society. Environmental Science Technology. Vol 27. No. 3.

Mitsch, W. and Jorgensen, S. 1989. Ecological Engineering: An Introduction to Ecotechnology. New York: John Wiley & Sons, Inc.

Naes, Arne. 1989. Ecology, Community, and Lifestyle: Outline of an ecosophy. Cambridge: New York: Cambridge University Press.

National Research Council (US). Committee on Sustainable Agriculture and the Environment in the Humid Tropics. Board on Agriculture and the environment in the Humid Tropics, Board on Agriculture and Board on Science and Technology for Intentional Development. 1992. Sustainable Agriculture and the Environment in the Humid Tropics. Washington, DC: National Academy Press. p. 5.

Nava, B. 1996. Manejo de Desechos Sólidos en el Distrito de Tuis, Cantón de Turrrialba, Costa Rica. Centro Agronómico Tropical de Investigación y Enseñanza. Subdirección de Enseñanza. Area de Estudios de Postgrado.

Nebel, B. J. 1990. Environmental Science: The Way the World Works, rd. de. New York: Prentice-Hall, Inc.

Peakall, D. 1992. Animal Biomarkers as Pollution Indicators. London: Chapman and Hall.

Peet, J. 1992. Energy and the Ecological Economics of Sustainability. Washington, D. C.: Island Press.

Piel, G. 1992. Only One World: Our own to make and to keep. New York: W. H. Freeman Company.

Prance, G.T. 1989. American tropical forest. In: Ecosystems of the world 14B: Tropical rain forest ecosystems. Lieth, H. and Werger, M.J.A. (eds). Amsterdam: Elsevier Science Publishers, p. 99-132.

Ragsdale, N. N. and Sisler, H. D. 1991. The Nature, Modes of Action, and Toxicity of Fungicides. In: CRC Handbook of Pest Management. Pimentel, D. (ed). Boca Raton, FL: CRC Press, pp. 461-496.

Recyplast, 1997. Information gathered during visit to the recycling plant in July 1997.

Risser, P., Lubchenco, J., Christensen, N., Dillon, P., Jacob, D., Johnson, P., Matson, P., Moran, N., and Rosswall, T. 1993. Ten-Year Review of The National Science Foundation Long-Term Ecological Research (LTER) Program. (Unpublished report)

Saaty, T. 1996. The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation. Pittsburgh, Pennsylvania: RWS Publications.

Saaty, T. and Kearns, K. 1991. Analytical Planning: The organization of Systems. The Analytic Hierarchy Process Series Vol. IV. Pittsburgh, Pennsylvania: RWS Publications.

Saaty, T. and Vargas, L. 1991. The Logic of Priorities: Applications of the Analytic Hierarchy Process in Business, Energy, Health and Transportation. The Analytic Hierarchy Process Series Vol. III. Pittsburgh, Pennsylvania: RWS Publications.

Saaty, T. and Vargas, L. 1994. Decision Making in Economic, Political, Social and Technological Environments with the Analytic Hierarchy Process. The Analytic Hierarchy Process Series Vol. VI. Pittsburgh, Pennsylvania: RWS Publications.

Sánchez, L. 1996. "Impacto de al Legislaciones Ambientales de Costa Rica y Holanda Sobre el Acceso al mercado para Algunos Sectores Productivos Bananeros de Costa Rica y Centro América." Universidad de Costa Rica.

Sánchez, O. and Barrientos, E. (CORBANA). 1992. Informe Estadistico de Exportaciones Bananeras 1970-1990. San Jose, Costa Rica: Corporación Bananera Nacional

Sanchez, O. and Barrientos, E. 1992. Informe estadistico de Exportaciones Bananeras 1970-1990. Corporacion National (CORBANA). San Jose, Costa Rica.

Snedecor and Cochran, 1967. Statistical Methods. Ames, Iowa: The Iowa State University Press.

Solórzano, R. del Camino, R., Woodward, R. Tosi, J., Watson, V., Vásquez, a., Villalobos, C., Jiménez, J., Repetto, R., and Cruz, W. 1991. Accounts Overdue: Natural Resource Depreciation in Costa Rica. Tropical Science Center, San José, Costa Rica and World Resource Institute, Washington, DC.

Soto, M. 1994. Desarrollo Sostenible de la Actividad Bananera. Authors personal notes for new book (Unpublished). San Jose, Costa Rica.

Soto, M. 1992. Bananos: Cultivo y Comercialización. San José, Costa Rica: Litografía e Imprenta LIL, S. A.

Tabora, P. 1991. Analysis and evaluation of agroforestry as a alternative environmental design in the Philippines. Netherlands: Kluwer Academic Publishers. Agroforestry Systems 14: 39-63, 1991.

The Packer. Feb. 5, 1994. Special Report: Global Produce.

Unión Mundial para la Naturaleza (UICN/ORMA, 1991) Oficina Regional para Mesoamérica., Evaluación del Impacto Socioambiental de la Actividad Bananera en Sarapiquí, Tortuguero y Talamanca. Draft Report. San José, Costa Rica.

United States Department of Agriculture (USDA), Agricultural Research Services. 1966. Mean Separation by the Functional Analysis of Variance and Multiple Comparisons. United States of America.

van den Bergh, J. and van der Straaten, J. 1994. Toward Sustainable Development: Concepts, Methods, and Policy. Washington, DC.: Island Press.

Veroutis, A. and Aelion, V. 1996. Design for Enviroment: An Implementation Framework. Total Quality Environmental Management. New York, N. Y.: John Wiley & Sons, Inc. Volume 5, Number 4. Summer 1996.

Wackernagel, M., Onisto, O. and Mata, M. 1995. Earth Reports for People: Inspiring New Visions to Make Sustainability a Reality. Earth Monitoring and Reporting Program. San Jose, Costa Rica: The Earth Council. An Earth Council Proposal.