Land use, national development and global welfare:

the economics of biodiversity's conservation and sustainable use

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Abstract

Material prosperity of countries depends on the use of their endowment of natural resources. Land management decisions, in particular, also affect the conservation of biological diversity, which is an asset for not only for the host country, but also for the rest of the world. There is a growing recognition that the contribution of biological resources both to sustainable national development and to the well being of the international community has been underestimated in the past.

Based on both theoretical analysis and case study material from Mexico, this dissertation discusses the land-use related factors giving rise to the loss of biodiversity, as well policy options and management practices that may allow sustainable land use and biodiversity conservation. The introductory chapter summarises the scientific and economic debate, including disagreements about the definition of biodiversity management objectives.

Chapter 2 analyses the sequence of land use changes typically observed in a number of tropical countries, and discusses interventions which could alter the incentives for land conversion.

The Convention on Biological Diversity stipulates that developing countries should be reimbursed for the "incremental cost" of activities that help conserving biodiversity. Chapter 3 proposes a model which addresses the allocative and incentive implications of the incremental cost mechanism.

The empirical part of the dissertation first discusses the social and economic factors that have been responsible over the last few decades for land us change and depletion of biological resources in the study area in Mexico (chapters 4 and 5). A linear programming economic model is then proposed, for simulating, at the farm level, further impacts over the next decade (chapter 5).

Based on a model of aggregation over space and time of farm-level decisions, chapter 6 analyzes the appropriate mix of conservation and sustainable use management options in the study area, providing estimates of their cost implications and discussing possible funding sources. Chapter 7 concludes with policy implications and options for future research.

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Acknowledgements, credits, disclaimer and dedication

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During my stay at CSERGE, I have received financial support from Italy's Consiglio Nazionale delle Ricerche (CNR), from the British Council, and from the ENI - Enrico Mattei Foundation. All of these are gratefully acknowledged. Professor Luigi De Rosa in CNR has been a constant point of reference and support.

Much of part three of the dissertation is based on work that I have undertaken during my assignment as a consultant to the Secretariat of the Global Environment Facility in Washington DC. In particular, the choice of the Sierra de Santa Marta (SSM) in Mexico as the subject of the applied part of the thesis is motivated by my role of task manager, co-editor and co-author of a case study on sustainable development and biodiversity conservation in SSM.

The study was core-funded by the PRINCE[1] program of the Global Environment Facility (GEF) and conducted between 1995 and 1996 in a partnership involving the GEF, a local

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[1] The Program for measuring Incremental Cost for the Environment (PRINCE) is core-funded and managed by the Secretariat of the Global Environment Facility. Started in 1993, PRINCE is a program of technical

the Proyecto Sierra de Santa Marta (PSSM), non-governmental organization, and CIMMYT, (Centro Internacional para el Mejoramiento del Maiz y Trigo), an international research centre on Maize and Wheat in the CGIAR network.

In the GEF, I wish to thank Ian Johnson, Kenneth King and Mario Ramos for mentoring and advicing, and for agreeing on a part-time work arrangement that has enabled me to complete the write-up of the manuscript. Other people in the GEF from whom I have received valuable technical and administrative support include Lesly Rigaud, Lesley Wilson, Patrice Diakite and Anne Bohon-Flanagan.

My work experience in Mexico has been both a challenging and an extremely gratifying one. My first debt of gratitude is with the more than five hundred members of rural communities in the Sierra de Santa Marta, who have been interviewed in field survey carried out for the GEF-PSSM-CIMMYT study, and have thus been the source of invaluable primary information. I am also sincerely grateful to the colleagues in the Proyecto Sierra de Santa Marta (PSSM) in Xalapa, Veracruz, with whom I have had the fortune of working for about a year and half. In particular, I have a debt of professional and human gratitude to Fernando Ramirez, Mayra Ledesma, Luisa Pare and Rafael Gutierrez.

Perhaps this will not be any compensation to the long hours of work that have been occasionally imposed on them, but I would like to say that I learnt a great deal from them: long conversations with Fernando and his colleagues have been the source of several of the ideas explored in the thesis.

Daniel Buckles, one of the founders of PSSM and a co-author of the GEF-PSSM-CIMMYT study, now with IDRC in Canada, has also been very helpful in creating the conditions for the development of the study. Diana Ponce Nava, in Mexico Ministry's for Environment and Natural Resources, has been an extremely valuable source of information and high level contacts.

studies aimed at testing methodologies, undertaking case studies and disseminating results in the area of incremental cost (King, 1993).

In Washington, a lot of personal gratitude goes to Francesca Manno and Paolo Cappellacci, for their support and patience as friends. Phoebe Millon has endured with me the final months of the writing up. The only feeling that surpasses my gratitude for her support, is the acknowledgment of the fortune I had in meeting her.

Credits

Some of the material contained in chapter 2 forms parts of a CSERGE working paper (Cervigni, 1993); a later version of it has been published in a Spanish language journal (Cervigni, 1994). Chapter 3 reproduces the article: Cervigni, R (1998), *Incremental Cost in the Convention on Biological Diversity*, Environmental and Resource Economics, 11: 217-241.

The description of the study area in chapter 4, the summary of the historical process of habitat loss in chapter 5, and the description of options for sustainable use of natural resources in chapter 6 draw, among other sources, on the above mentioned GEF - sponsored study (Cervigni & Ramirez, 1997). The information collected for, and generated by, that research provides the background for the analysis, modeling exercises and conclusions of chapters 4, 5 and 6, which amount to original contributions of this dissertation, not included in the GEF-PSSM study.

Disclaimer

Despite the long list of people that have been supporting in various ways my work, I remain the only one responsible for errors and omissions.

Dedication

As my parents are the addressees, the dedication of this dissertation is written in Italian:

Questa tesi è dedicata ai miei genitori Rita e Giovanni, a cui devo, oltre alla fortuna di essere venuto al mondo, la mia istruzione, i miei valori etici fondamentali, e, a parziale loro rassicurazione per i lunghi anni di assenza da casa, l' amore per la lingua e la cultura del mio paese.

0. Purpose and scope of the dissertation

Material prosperity of countries depends on the use of their endowment of natural resources. Land management decisions, in particular, also affect the conservation of biological diversity, which is an asset not only for the host country, but also for the rest of the world. There is a growing recognition that the contribution of biological resources both to sustainable national development and to the well being of the international community has been underestimated in the past. Ecological and biological research is increasingly pointing to the possibility that "low" diversity of life forms may threaten the satisfaction of material needs, and imperil the life support functions of natural systems.

Based on both theoretical analysis and case study material from Mexico, this dissertation discusses the land-use related factors giving rise to the loss of biodiversity, as well as funding and policy options, and management practices, that may allow sustainable land use and biodiversity conservation.

The introductory chapter (chapter 1) summarises the main terms of the scientific and policy debate, highlighting areas of uncertainty and disagreement about the definition of biodiversity management objectives. It also provides a conceptual framework for the analysis of the biodiversity problem in economic terms.

Conversion of forested areas to pasture and agriculture, especially in the tropics, has often been stressed as the single most important factor of habitat alteration likely to result in biodiversity loss. Chapter 2 proposes a framework for analysing the sequence of land use changes typically observed in a number of tropical countries, as well as for discussing different policy interventions which could alter the incentives for land conversion.

Land conversion may improve the well-being of some sectors of developing countries' society, but it is likely to make the rest of the world worse off. How can the international community provide the resources necessary for developing countries to modify their "baseline" course of action? The Convention on Biological Diversity stipulates that developing countries qualify for receiving financial support from developed countries to meet the "incremental cost" of undertaking activities that result in the conservation of biodiversity. Chapter 3 proposes a model which addresses the allocative and incentive implications of the incremental cost mechanism.

How does the process of land use change happen in real life, and what kind of options can be devised to provide local resource users with incentives for conservation and sustainable use of biodiversity? The empirical part of the dissertation attempts to answer these questions based on a case study in the region of Sierra de Santa Marta, Mexico. It first discusses the social and economic factors that have been responsible over the last few decades for various processes of land us change and depletion of biological resources in the study area (chapters 4 and 5); an economic model is then proposed, for simulating, through use of linear programming techniques, further impacts, at the farm level, over the next decade (chapter 5).

Based on a model of aggregation over space and time of individual household decisions, Chapter 6 considers the problem of the appropriate mix of conservation and sustainable use management options in the study area, discussing cost implications and possible funding sources. Chapter 7 formulates tentative policy conclusions and sketches lines of possible future research. Figure 1 illustrates the structure of the dissertation.

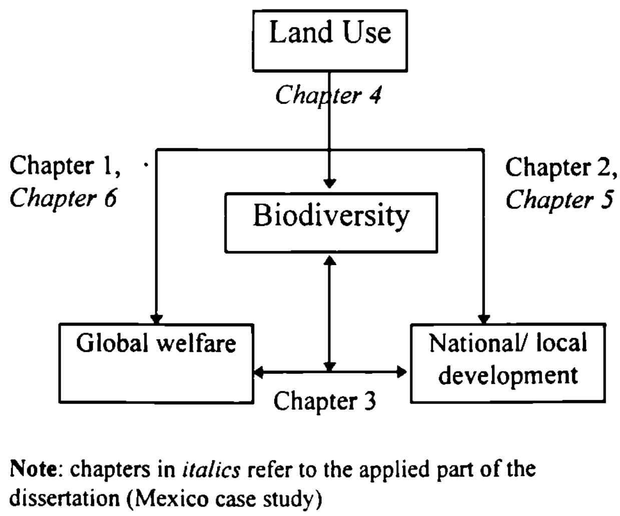

Figure 1: structure of the dissertation

Part I - Introduction

1. Biodiversity conservation: the background

1.1. Introduction

There are probably few topics of the public debate on the environment that have generated over the last couple of decades as much interest as biological diversity, often abbreviated in biodiversity. Casual examination of the existing literature confirms this statement: reference books (Heywood, 1995) and bibliographies (Polasky, Jaspin et al., 1996) on the topic are becoming increasingly voluminous. Further evidence can be gathered if one tries to conduct some simple keyword searches on different on-line research tools, such as those listed in Table 1-1. The table reports the number of occurrences of the phrase “biological diversity” and of the word “biodiversity” in a number of repository of information, such as catalogues of libraries managed by academic, government, and international organisations, databases of referred journals, the World Wide Web.

The actual numbers need to be interpreted with caution, since they are likely to conceal multiple counting of the same items. Nevertheless, they provide an order of magnitude of the volume of information that is currently generated and gathered on the topic of biodiversity. The table also illustrates the variety of disciplines that are being involved in the debate (not only natural sciences such as ecology and biology but also social sciences like economics). It further highlights the different fora where the information is presented and discussed: books, journal articles, conference presentations and proceedings, and so forth.

Table 1-1: References to biological diversity and biodiversity from miscellaneous sources of on-line information . (Source: author's searches, October 1996)

Source	Type/ Description	Items returned, "Biological diversity"	Items returned, "Biodiversity"
Excite	WWW search engine	472,987	36,025
Magellan	WWW search engine	53,300	4,446
Infoseek	WWW search engine	51,918	2,371
Lycos	WWW search engine	11,670	6,001
WorldCat	Database of books and other materials in libraries world-wide	1,648	779
Environment	Comprehensive, multidisciplinary coverage of relevant fields across the environmental sciences from all the primary sources for 11 abstracts journals for the current year plus 5 previous years.	1436	980
Jolis	Catalogue of World Bank's library system	513	213
LOCIS	Catalogue of Library of Congress	430	237
ArticleFirst	Index of articles from nearly 12,500 journals in science, technology, medicine, social science, business, the humanities, and popular culture. 1990 to the present	296	966
PaperFirst	Over 580,000 papers included in every congress, conference, exposition, workshop, symposium, and meeting received at The British Library from October 1993 to the present	208	921
Books in print	1.8+ million records of in-print, out-of-print, and forthcoming books from over 44,000 North American publishers.	149	218
Proceedings	Over 19,000 citations of every congress, symposium, conference, exposition, workshop and meeting received at The British Library from October 1993 to the present.	28	8
Econlit	American Economic Association Index of economic literature	23	60

Such a massive production of information indicates that the topic is regarded as important in the perception of governments, the academic and scientific community, and the public at large. In recent times, concerns about the conservation of biodiversity have brought about major international actions, such as the negotiation and signing of the Convention on Biological Diversity in 1992 and the establishment of the Global Environment Facility, replenished in 1994 for US$ 2 billion for projects in four "global environment" focal areas, including conservation of biodiversity. The assistance strategy of multilateral organisations (World Bank, 1995) and of bilateral donors (Abramovitz, 1991) is being reshaped to take into account biodiversity concerns. Despite the initiatives already undertaken, calls for further commitments to the cause of biodiversity conservation are often being made: estimates have been produced on the amount of resources needed to augment the sustainable development strategy laid out in Agenda 21(UNCED, 1993)[1] with specific actions targeted at biodiversity conservation.

But the large numbers of Table 1-1 also suggest that the topic is a complex one, and that it lends itself to a number of different analyses and types of scientific, political and policy approaches. Because of the consensus that biodiversity conservation is an important issue, and because of the significant amount of resource being mobilised to address it (and of the even larger amounts that are being called for), stakeholders of different constituencies are actively engaged in intense research, dissemination and persuasion campaigns, to steer the public debate (and the flow of funding) in the preferred directions. In spite of the growing attention to biodiversity and of the broad range of stakeholders, it is often argued that our understanding of the nature, causes and solutions to the problem is far from adequate[2].

The aim of this chapter is to provide a general overview of the nature of the problem of biodiversity. This should enable the reader to put into context the theoretical and empirical analysis presented in subsequent chapters of the dissertation.

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[1] The Secretariat of the UN Conference on Environment and Development has estimated the average annual costs (1993-2000) of implementing in developing countries the activities in Agenda 21 to be over $600 billion, including about $125 billion on grant or concessional terms from the international community. The Conference secretariat has also estimated that the average total annual cost (1993-2000) of implementing activities related to biodiversity conservation to be about $3.5 billion, including about $1.75 billion from the international community on grant or concessional terms. All of these figures are indicative and order-of-magnitude estimates only, and have not been reviewed by Governments. Actual costs will depend upon, inter alia, the specific strategies and programmes Governments decide upon for implementation. It may be argued that some portion of the second figure (i.e. the cost of actions specifically targeted at biodiversity conservation) may be reduced by appropriate allocation of resources included in the first figure, which determine a "baseline" course of actions countries would undertake to pursue national sustainable development objectives. Issues related to the determination of "baseline", "alternative" and "incremental cost" of biodiversity conservation are addressed in theoretical terms in Chapter 3.

[2] The Preamble to the Convention on Biological Diversity express the Contracting Parties' awareness "of the general lack of information and knowledge regarding biological diversity and of the urgent need to develop scientific, technical and institutional capacities to provide the basic understanding upon which to plan and implement appropriate measures".

1.2. The debate on biodiversity

Driving in intricate territories is impossible without a road map. Figure 1-1 proposes a simplified framework to break down into four discrete components the debate about biodiversity. The four components are a) the way the problem is formulated, b) the identification of the causes of the problem, and the analysis of their interaction, c) the identification of actions that would tackle the causes of the problem, and d) the situation that is expected to prevail once the remedial actions are undertaken (and, conversely, the situation that would arise in case of inaction).

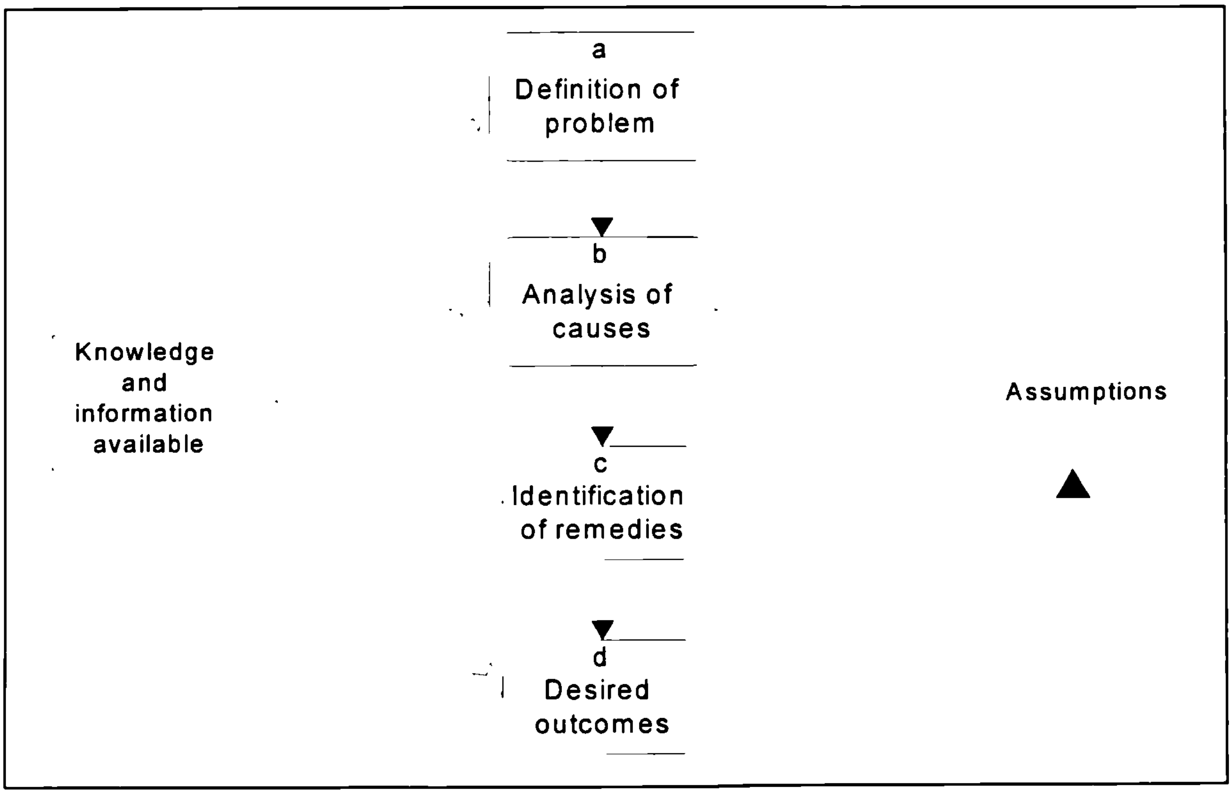

Figure 1-1 The building blocks of the debate on biodiversity

The figure also stresses some additional points about the ***a-d*** sequence. The first is that it crucially relies on the existing knowledge and understanding of the natural and social phenomena under investigation, and on the available information (dotted box and lines on the left hand side of the figure). The second point is that at each steps of the sequence, assumptions need to be used to fill the gaps in both the understanding of the processes, and in the information available. Finally, the dotted arrow at the bottom of the diagram suggests that changes in the information available on the problem may determine a revision and modifications of the assumptions used in the formulation and analysis of the problem. The following sections elaborate on each of the building blocks of the biodiversity debate.

1.3. Defining the biodiversity problem

Figure 1-2 proposes a schematic summary of the steps which are involved in defining the problem of biodiversity. The first element is the statement of the problem. This can take several forms, each one with its implications in terms of analyses of the causes, and development of corrective strategies. The second step is the precise definition of the different terms used in the statement of the problem. Once semantic precision is achieved, further clarification of the problem requires definition of the indicators which may be used to enable quantitative measurement of the terms employed in the definition of the problem. The dotted triangles allude to the fact that behind each way of formulating a particular problem there are underlying basic motivations, which can be of different nature (ethical, economic, social, etc.). Moreover, each set of underlying motivations will use a particular theoretical and methodological toolkit for analysing the problem at hand.

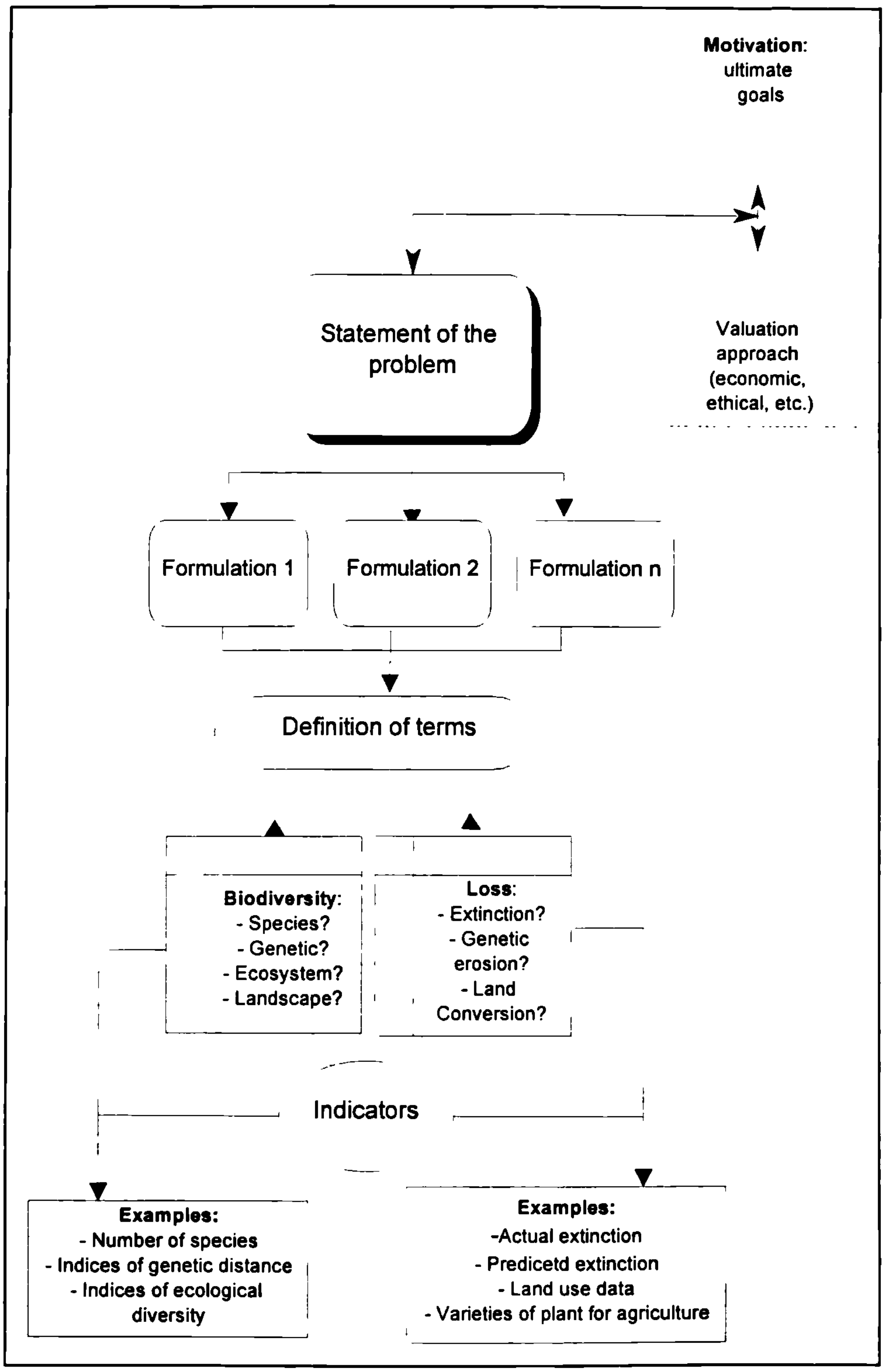

Figure 1-2 Defining the biodiversity problem

1.3.1. Statement of the problem

Despite the large production of information on the topic, the public debate on biodiversity has been fostered and shaped over the least decade by a relative small number of publications. These have raised the issue of biodiversity conservation in a number of highly visible fora, and have contributed to the inclusion of the topic in the agenda of national and international policy makers.

Text Box 1-1 provides a list of quotations from some of those key publications. Because of their impact on the public debate, they represent important sources for defining the way in which the biodiversity problem is being stated. The table also includes a quote from the preamble of the Convention on Biological Diversity, which indicates the extent to which concerns expressed in public debates have been incorporated in international policy and legal instruments.

One way of expressing the thread that links the different formulation of the problems is as follows. Human societies and natural systems have always coexisted in some form of dynamic equilibrium. Over the last century, that equilibrium is being put under increasing pressure because of the expansion of human activities at the expenses of the ability of natural systems to provide inputs to those activities and absorbing their outputs.

There is one particular aspect of the broken equilibrium that is particularly worrying because of the irreversibility of its effects. This aspect has to do with the prevailing pattern of life forms, and its ability to: a) meet the direct material needs (food, shelter, health) of the human population; and b) maintain the life-support function of natural systems and natural processes (thereby guaranteeing indirectly the satisfaction of human material needs). The condensed label that has been coined to capture these concepts is biodiversity. The way the term is used in this context implies that "low" "diversity" of "life forms" threatens the satisfaction of material needs, and imperils the life support functions of natural systems.

"(...) we are rapidly altering and destroying the environments that have fostered the diversity of life forms for more than a billion years" "(...) science is discovering new uses for biological diversity in ways that can relieve both human suffering and environmental destruction. (...) much of the diversity is being irreversibly lost through extinction caused by the destruction of natural habitats, again especially in the tropics" (Lugo, 1988).

"As the 21st century approaches, the world is being impoverished as its most fundamental capital stock -its species, habitats, and ecosystems -erodes. Not since the Cretaceous era ended some 65 million years ago have losses been so rapid and great. If the trend continues, one quarter of the world' s species may be gone by 2050" (Reid & Miller, 1989).

"In the late 20th century, we are coming to realise that biological resources have limits, and that we are exceeding those limits and thereby reducing biological diversity(...) The combined destructive impacts of a poor majority struggling to stay alive and an affluent resource- consuming minority are inexorably and rapidly destroying the buffer that has always existed, at least on a global scale, between human resource consumption and the planets productive capacity" (McNeely, Miller, Reid, Mittermeier, and Werner, 1990).

"In the remote past, human actions were trivial when set against the dominant process of nature. No longer. The human species now influences the fundamental processes of the planet. Ozone depletion, world-wide pollution, and climate change are testimonies to our power. (...) Unless we protect the structure, functions and diversity of the worlds natural systems -on which our species and all others depend -development will undermine itself and fail(...) The conservation of biodiversity is fundamental to the success of the development process(...) conserving biodiversity is not just a matter of protecting wildlife in nature reserves. It is also about safeguarding the natural systems of the earth that are our life-support systems; purifying the waters; recycling oxygen, carbon and other essential elements; maintaining the fertility of the soil; providing food from the land, freshwaters and seas; yielding medicines, and safeguarding the genetic richness on which we depend in the ceaseless struggle to improve our crops and livestock." (World Resources Institute, 1992).

"It is evident that a certain level of biological diversity is necessary to provide the material basis of human life: at one level to maintain the biosphere as a functioning system and, at another, to provide the basic materials for agriculture and other utilitarian needs" (Groombridge, 1992).

"The Contracting Parties, (...) conscious of the importance of biological diversity for evolution and for maintaining life sustaining systems of the biosphere,(...) concerned that biological diversity is being significantly reduced by certain human activities, (...) aware that conservation and sustainable use of biological diversity is of critical importance for meeting the food, health and other needs of the growing world population, for which purpose access to and sharing of both genetic resources and technologies are essential, (...) have agreed as follows:(...) " (UNEP, 1992).

"(...) the state of the Earth's biological systems is of fundamental importance for human society (...) our influence on these systems is increasing exponentially. During the last decade, much of the interest and concern has focused on the issue of biodiversity. The scientific and social concepts and issues involved are highly complex and often poorly understood and badly explained.(...) Are we facing a global biodiversity crisis, or indeed are we in the midst of one, as several authors have suggested? These and similar questions have been asked during the past two decades, arising out of a growing concern at the prospect of a rapidly accelerating loss of species, populations, domesticated varieties and natural habitats such as tropical rain forests and wetlands. Recent estimates suggest that more than half the habitable surface of the planet has already been significantly altered by human activity" (Heywood & Baste, 1995).

Text Box 1-1: selected statements of the biodiversity problem

Words like "low", "diversity", and "life forms" have an intuitive appeal, but without any additional qualification are not capable to give operational guidance to research, policy and management. The next step in the present analysis (and in fact in many of the publications referred to in Text Box 1-1) is to attempt to clarify the terms used in the statement of the problem; this is the objective of section 1.3.2. Before moving on to it, two remarks are in order.

The first one regards underlying motivations. In all of the quotes listed in Text Box 1-1 the ultimate concern is for human well-being. The worthiness of actions intended to conserve natural systems needs to be evaluated on the basis of their contribution to mankind's welfare. The conceptual and analytical valuation toolkits that can used in this approach are based on social sciences like economics, anthropology, sociology.

Despite its self-evident justification, this is not the only possible approach. Supporters of alternative paradigms, such as the Gaia hypothesis (Lovelock, 1987), argue that there need not be any justification of nature conservation in terms of human well-being. Conservation can be motivated by concerns for the well-being of the entire planet, regarded itself as a living organism; or by stewardship obligations that the human race would have towards other species and future generations. Under these premises, valuation exercises would not be conducted with the analytical tools of the social sciences; other disciplines such as ethics or theology would need to be employed.

The second remark is that, in a human-centred approach to environmental management, ultimately what matters are the welfare consequences of alternative ways of managing natural resources. Concerns such as those summarised in Text Box 1-1 are not for diversity in itself, but for diversity as instrumental to human well-being. In other words, the objective is not necessarily to conserve diversity, but to conserve the ability of natural system to support human well-being on a sustainable basis.

Such a welfare-oriented approach makes things more complicated for defining, measuring and managing biological resources. It may well be that the welfare-generating properties of natural systems will be enhanced not necessarily by conserving diversity of biological resources in an indiscriminate fashion; but for example, by concentrating efforts on selected association of genes, species or ecosystem where, according to some specified criterion, there is high likelihood of identifying welfare-enhancing properties.

Or one could argue for management strategies that maximise the evolutionary potential of specific communities, in the assumption that what matters most, is not conserving static diversity at any given point in time, but rather to preserve natural processes, i.e. the ability of natural systems to evolve over time and to respond to changing environmental challenges. These and other approaches to the relationship between properties of natural systems and diversity have significant implications in terms of choosing among alternative options of policy and management.

1.3.2. Defining terms

1.3.2.1.Defining and measuring diversity

As exemplified by the quotations listed in Text Box 1-2, one recurrent complaint in the biodiversity literature is that calls for biodiversity conservation are often not followed by an indication of what exactly should be conserved.

"Within six years, the word 'biodiversity' has exploded into the vocabulary of the popular press, governmental and intergovernmental reports, scientific papers and meetings. (...) It seems reasonable to ask of a word that is so widely used, just what is it supposed to mean" (Harper & Hawksworth, 1994).

"There is a broad consensus that biodiversity should be protected, but it is not at all clear what this means in policy and practical terms. This uncertainty is in part a consequence of divergent views as to the exact meaning of biological diversity" (Heywood, 1992).

"At the Earth summit in 1992, the more than 150 nations that signed the International Convention on Biological Diversity signalled their commitment to the conservation of biodiversity and their obligation to monitor its status. But do we have the means of measuring whether the objective of biodiversity conservation is being achieved? Indeed, do we even know what the objective of biodiversity conservation should be?" (Reid, 1994).

"When individuals or organisations stress the need to save nature or natural biodiversity, it is not always clear what are they talking about. Programs to safeguard pristine environments are chimerical" (Smith, 1996).

Text Box 1-2

In some cases, the absence of explicit definitions may be due to the fact that people assume that everybody else shares the same intuitive notion of what biodiversity means, which would imply that biodiversity is a “pseudcognate” term (Williams & Humphries, 1994). However, there are several intuitive shared notions of biodiversity (Harper & Hawksworth, 1994), as there are different disciplines that deal with biodiversity from different perspectives. Practitioners of evolutionary biology, taxonomy, systematics, ecology, genetics and population biology have different (and not always converging) approaches to biodiversity. The approach of community ecologists, for example (Magurran, 1988), leads to measures that combine information on species richness with information on relative abundance of each species; whereas conservationists emphasise vulnerability to extinction (Williams & Humphries, 1994).

It has also been argued that it is in fact desirable to have multiple views and definitions of biodiversity, as this broadens the constituency that supports the cause of conservation (Heywood, 1992). The counter-argument to this is, of course, that the political consensus created by a broad biodiversity constituency may be quickly dissipated by disagreement on policy prescriptions in presence of multiple definitions, entailing mutually exclusive choices on the operational use of scarce funds.

Partly because of the fact the biodiversity means different things to different scientists and different constituencies, definitions used in policy documents, scientific overviews and legal instruments are quite general, as exemplified by the quotes listed in Text Box 1-3. A common feature of several definitions is the distinction of the genetic, species and ecosystem levels of biodiversity. Let us consider indicators that have been proposed for the measurement of diversity at these levels.

"Biological diversity encompasses all species of plants, animals and micro-organisms and the ecosystems and ecological processes of which they are part. It is an umbrella term for the degree of nature's variety, including both the number and frequency of ecosystems, species or genes in a given assemblage" (McNeely, Miller, Reid, Mittermeier, and Werner, 1990).

"For the purposes of the Global Biodiversity Assessment, biodiversity is defined as the total diversity and variability of living things and of the system of which they are part" (Heywood & Baste, 1995).

"«Biological diversity» means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. « Biological resources » includes genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity" (UNEP, 1992)

Text Box 1-3: Definitions of biodiversity

Indicators of Genetic Diversity

Indicators of Genetic Diversity have the purpose of measuring the degree of variability within different groupings of individuals (local collection of individuals, species, or higher taxonomic group). Genetic differences can be measured in terms of phenotypic traits, allelic frequencies, or DNA sequences.

Phenetic diversity is based on measures of phenotypes, individuals which share the same characteristics. These measures are usually functions of the variance of a particular trait, and often involve readily measurable morphological and physiological characteristics. The disadvantage of measures of phenetic diversity is that their genetic basis is often difficult to assess, and standardised comparisons are difficult when populations or taxa are measured for qualitatively different traits.

Allelic diversity: Variants of a same gene are called alleles. Allelic diversity may be measured at the individual level, or at the population level. Average expected heterozygousity (the probability that two alleles sampled at random will be different) is commonly used as an overall measure of diversity. A number of different indices and coefficients can be applied to the measurements to assess genetic distance (Antonovic, 1990).

Sequence variation: A portion of DNA is sequenced using the polymerase chain reaction technique (PCR). A very small amount of material, perhaps one cell, is required to obtain the DNA sequence data, so that only a drop of blood or single hair is required as a sample. Closely related species may share 95 percent or more of their nuclear DNA sequences, implying a great similarity in the overall genetic information.

Measurement of Species Diversity

There are a number of dimensions of diversity at the species level, including overall species richness, relative abundance and relatedness of different species. Often, species richness - the number of species within a region or given area - is used almost synonymously with species diversity.

In its ideal form, species richness would consist of a complete catalogue of all species occurring in the area under consideration, but this is not usually possible, unless it is a very small area. Species richness measures in practice therefore tend to be based on samples. Such samples consist of a complete catalogue of all organisms within a taxa found in a particular area, or it may consist of a measure of species density in a given sample plot, or a numerical species richness defined as the number of species per specified number of individuals or biomass.

A more informative measure of diversity would also incorporate the 'relatedness' of the species in a fauna (Williams & Humphries, 1994; Reid, McNeely, Tunstall, Bryant, and Winograd, 1993). The intuition is that the unit of value is not so much the species, as the evolutionary processes that have led to it. Two areas with the same number of species may not be equally valuable if one contains species which are "more diverse" from each other in terms of evolutionary processes.

Measures belonging to this group augment species richness with measures of the degree of genealogical difference. Derived from cladistic (family tree) methods, these measures include a) the weighting of close-to-root species, b) higher-taxon richness, c) spanning-tree length and d) taxonomic dispersion (Williams & Humphries, 1994). Close-to-root species and higher-taxon richness explicitly use polarity from the root of the tree to weight higher-ranking taxa or 'relic' species as distinct survivors of long-independent lineages and original conduits of genetic information. In contrast, spanning tree length and taxonomic dispersion are more general tree measures of sub-tree 'representativeness'. Persisting conceptual difficulties in actual implementation of cladistic measures as well scarcity of the necessary data imply that in the short run use of cruder indicators of richness of genera or families will be dominant in rapid assessment of species diversity.

Measurement of Community Diversity

Many environmentalists and ecologists put emphasis on conservation of biodiversity at the community level. Several different 'units' of diversity are involved at the supra-species level, including the pattern of habitats in the community, relative abundance of species, age structure of populations, patterns of communities on the landscape, trophic structure, and patch dynamics. There are disadvantages as well as advantages in using measures of community diversity. One disadvantage is that unambiguous boundaries delineating the various units of diversity at the community level do not exist. On the other hand, the advantage is that by conserving biodiversity at the ecosystem level, not only are the constituent species preserved, but also the ecosystem functions and services protected. These include pollutant cycling, nutrient cycling, climate control, as well as non-consumptive recreation, scientific and aesthetic values (see for example, (Norton & Ulanowocz, 1992)).

Because of the many ways of defining biodiversity at community or ecosystem level, there is correspondingly a range of different approaches to measuring it. As (Reid, McNeely, Tunstall, Bryant, and Winograd, 1993) explain, any number of community attributes are components of biodiversity and may deserve monitoring for specific objectives. There are several generic measures of community level diversity. These include biogeographical realms or provinces, based on the distribution of species, and ecoregions or ecozones, based on physical attributes such as soils and climate. These definitions may differ according to scale. For example, the world has been divided into biogeographical provinces, or more fine-grained classifications which may be more useful for policy-making. The latter include the definition of `hotspots', (Myers, 1983) based on the number of endemic species, and `megadiversity' states (Mittermeier & Werner, 1990).

Discussion

The previous section has reviewed various approaches to measuring diversity at the genetic, species and ecosystem level. The very existence of a multiplicity of measures suggests that the discipline (or art) of measuring diversity does not necessarily provide policy makers with clear cut guidelines for action.

A more fundamental conceptual problem is related to the fact that most of the measures reviewed seem to imply a <u>static</u> approach to the resource management problems. Much of the debate on indices of biodiversity is focused on the following question (see (Harper & Hawksworth, 1994; Humphries, Williams et al., 1995; Forey, Humphries et al., 1994): let us take a number of sites <u>in a given instant of time</u>. What are sensible criteria to invest resources in the most "biodiverse" of those sites?

This may imply an implicit objective of "freezing" the natural system at the current level of the diversity measures employed, with no particular consideration given to the evolutionary dimension of natural processes. To quote again (Heywood & Baste, 1995), "Do we want to conserve particular biological states or to preserve natural processes?"

Another problem is related to the relationship between diversity and ecosystem functions. As observed in 1.3.1, the fundamental reason why we should be concerned about biodiversity loss is its negative impact on ecosystem functions. It is commonly assumed that any reduction of diversity decreases ecosystem function. There is however an alternative view, which has recently regained prominence in the scientific debate (Grime, 1997): the relationship between diversity and ecosystem functions need not be monotonously increasing.

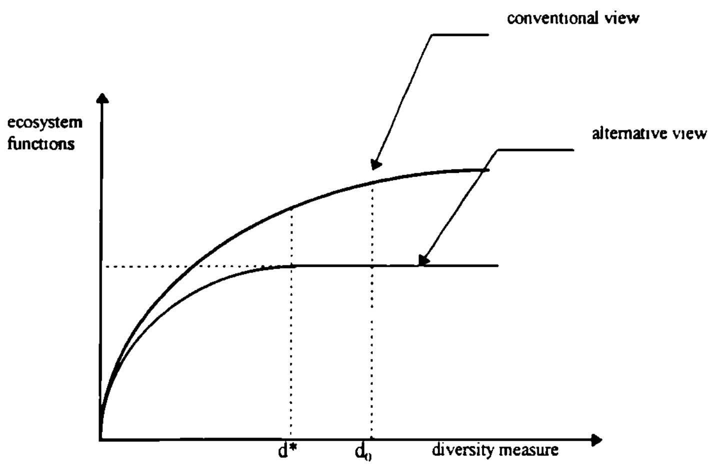

Figure 1-3. Diversity and ecosystem function: alternative views

Figure 1-3 proposes a simplified account of the basic argument. The conventional view is represented by the ever increasing upper curve: decreases in diversity always imply lower provision of ecosystem functions. The alternative paradigm maintains that there may in fact be a critical level of diversity (d*), associated to the presence of species with no substitutes for the delivery of particular ecological services. However, higher levels of diversity (that is, in excess of d*) may in fact be found to be associated with non-increasing levels of ecological services. The policy implications is that impacts of a given reduction in loss will critically depend on what is the initial level of diversity, relative to the critical level d*. If initial diversity d_0 is located to the right of d*, as in Figure 1-3, diversity losses in the tract d_0 - d* are associated to non-decreasing provision of ecological services, and hence, most likely, to non decreasing level of human welfare.

A final problem related to the "static" approach of biodiversity measurement has to do with management. "Static" measures of diversity provide the basis for constructing algorithms to allocate a limited budget to a number of sites which "score high" in terms of the selected measure. However, the outcome of the optimisation process may tell us little about the actual use that should be made of the resources allocated. If the implicit assumption is that resources should be allocated to outright preservation[3], then the entire range of semi-natural, man-altered ecosystems (which are still regarded as important diversity havens[4]) is considered unworthy of being included in the resource allocation problem. If, on the other hand, the management problem is more general than the simple choice "strict conservation versus full development", than what is needed is not only appropriate measures of diversity, but also an analysis of the process of loss of diversity over time[5]. Such an analysis should give indications about which management practices are more damaging to which measure of diversity, so that decision makers can evaluate option for arresting those practices.

1.3.2.2.Defining and measuring loss

1.3.2.2.1.Species loss

Species are lost when they become extinct. Hence, human-induced decreases in species diversity are measured by increases in extinction with respect to natural extinction processes. Because the total number of species is likely to vary over time, meaningful comparisons between current and past extinction must be based on rates. At any point in time t, the process of lost will be more severe that in pre-human times if $E^h < E_t$.

With regard to the first term of the comparison, background rate of extinction are mainly based on fossil records of marine invertebrate (Pimm, Russell et al., 1995)[6].

Estimates of current extinction rates are troublesome for two reasons. The true value of the rate's denominator, i.e. the overall number of species existing at any given point in time, is not known[7].

[3] Recent estimates suggest that more than half the habitable surface of the planet has already been significantly altered by human activity (Heywood & Baste, 1995).

[4] For example, for a discussion of the biodiversity significance of second-growth forests, see (Brown & Lugo, 1990) and (Kemp, 1992) quoted in(Heywood, 1992).

[5] There are some examples in the literature, e.g. (Moran, Pearce et al., 1996), of studies which incorporate degree of threat into measures of priority sites for conservation. The choice of the threat indicator may implicitly contain an analysis of the process eventually leading to loss.

The numerator of the rate is the per-period number of species lost. Few estimates of extinctions are in fact based on actually documented extinctions (which would in fact produce very low rates of loss (Heywood & Baste, 1995; Gentry, 1996)[8]. Many studies estimate loss through models based on the species-area relationship. This relationship, which merits and limits will be elaborated upon in more detail in chapter 2, stipulates that decreasing habitat size commands decreasing number of species.

This approach gives rise to predictions over the next century that the projected loss of species might be expected to be as high as 20 to 50% of the world's total (see Table 1-2), which represents a rate between 1,000 to 10,000 times the historical rate of extinction (Lugo, 1988; Barbault & Sastrapradja, 1995). One aspect of particular relevance, is that the species-area relationship estimates the number of species which will be committed to extinction as a result of habitat loss. The ultimate occurrence of extinction, as well as its timing, however, is not an automatic result of land conversion, but will be affected by a number of variables, including demographic parameters of the population living in shrinking areas, and species and ecosystem management .

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[6] An alternative approach for estimating rates of loss in pre-industrial times is to use the species-area relationship (see below in the text) and use information on past land conversion and likely habitat losses.

[7] It is thought that there are somewhere between 5 to 80 million species on earth. A conservative estimate is 13-14 million of which only 1.75 million have been described some in only rudimentary detail(Barbault & Sastrapradja, 1995)

[8] "The rate at which species are likely to become extinct in the near future is very uncertain. If we look at the number of recorded species extinctions since 1600 it is barely four figures, which contrasts with several predictions of imminent or actual massive extinctions that have been made in the period 1980-95, based mainly on a species-area model derived from the field of island biogeography" (Heywood, 1992). "..to date, gratifyingly few extinctions of plant species are known to have occurred. We might still have time to save nearly all plant species of the neotropics" (Gentry, 1996)

Table 1-2 Estimates of the Current Rates of Species loss

Estimate of Loss	Basis	Source
33-50% of species by 2000	forest area loss	Lovejoy (1980)
50% of species by 2000	forest area loss	Ehrlich (1981)
25-30% of species in 21st century	forest area loss	Myers (1989)
33% of species in 21st century	forest area loss	Simberloff (1986)

(Groombridge, 1992) and references

1.3.2.2.2.Genetic erosion

Each individual animal or plant belongs to a species. Yet, it differs from other individuals belonging to same species, according to the way it draws from the broad genetic pool shared by the species. The larger the genetic pool, the larger the chance of any given individual to possess traits improving the chance of resistance (and hence surivival) to external stress factors, such as predators, climate, diseases, habitat disruptions and so forth.

Table 1-3 Genetic uniformity in selected crops. Source:(Groombridge, 1992) **and references**

Crop	Country	Number of varieties
Rice	Sri Lanka	From 2,000 varieties in 1959 to 5 major varieties today; 75% of varieties descended form one maternal parent
Rice	India	From 30,000 varieties to 75% o f production from less than 10 varieties
Rice	Bangladesh	62% of varieties descended from one maternal parent
Rice	Indonesia	74% of varieties descended from one maternal parent
Wheat	USA	50% of crop in 9 varieties
Potato	USA	75% of crop in 4 varieties
Cotton	USA	50% of crop in 3 varieties
Soybeans	USA	50% of crop in 6 varieties

It is often argued that human activities induce a reduction in the genetic variability of several species, especially of plants for use in agriculture. The "green revolution" has determined a dramatic increase in the productivity of the world's major crops through the introduction of a relatively small number of high- - yielding varieties (HYV). As the area devoted to growing the HYV increased, traditional, unimproved, or lower yields cultivars tended to disappear, entailing the loss of potentially valuable genetic information stored in those varieties (Swanson, Pearce et al., 1994; Swanson, 1995). Table 1-3 provides examples of the extent of genetic uniformity for selected crops and countries.

The process of homogenization of plant for agriculture is a reason for concern (Groombridge, 1992), in that increases in crop yields have been accompanied by increase in their variability, allegedly due to increased susceptibility to pests, diseases and changes in weather patterns.

1.3.2.2.3.Loss at the community level

As discussed earlier, there are many different way of classifying biological communities; for example, classification based on community structure and function differ from classifications based on species composition (Bisby, Coddington et al., 1995). In terms of scale, global systems like life zones (Holdridge, 1967), ecoregions (Bailey & Hogg, 1986) or bio-geogrpahic realms and provinces (Udvardy, 1975) coexist with systems used at the regional scales, where landscapes are normally identified.

Human activities that have an impact on biological community on the basis of a particular classification, may go undetected when a different classification is used. For example, a reduction in landscape diversity due to the increase of a particular land use may not necessarily imply reduction in the diversity of bio-geographic provinces. Clarification of the relevant unit of classification and of the spatial scale of analysis is thus of particular importance to address the complex methodological issues related to measuring loss at the community level.

1.4. Analysing the causes of the problem

Several causes of loss of biodiversity can be easily enumerated. There is a significant portion of the literature (Ostrom, 1995; World Resources Institute, 1992; Pearce & Moran, 1994) that discusses the causes of loss. On top of scholarly analysis, reviewing program and project documents of activities implemented by development agencies and conservation institutions[9] may also give a good idea of the range of causes addressed in practice by biodiversity conservation projects.

What is not so easy, is to define a *single* factor, or a few single factors, most responsible for biodiversity loss. It appears that in most cases a *multiplicity* of causes of demographic, economic, social and institutional nature interact in determining unfavourable conditions for biodiversity conservation. This is because many of the developing countries hosting the largest share of biological resources largely depend on the exploitation of the natural resource base for securing their livelihood. As a result, a large variety of social and economic groups, each one motivated by different drives, interact in determining the actual pattern of exploitation of the country's biological resources.

Figure 1-4 conceptualizes the problem of analyzing the causes of biodiversity loss. The starting point is of course the way the problem is formulated in the first place: different problem statements warrant different identification of causes and different analysis of their interaction. For example, if the initial emphasis is on the process of loss at the genetic level, different causes may be identified from those that may be brought into the picture if the original question concerned conservation of diversity at the ecosystem level.

The second step is a classification of factors with detrimental impacts on biodiversity, based on their position in the causation chain eventually leading to loss. A further step has to do with the organization of the causes of loss not only in an ordinal ranking, as in block A, but also in terms of actual relationships of cause and effect amenable to quantitative analysis.

This additional step is depicted in block B, which also stresses that the more sophisticated the quantitative model, the more it will be able to address not only direct cause - effect linkages, but also feedback processes connecting various elements at different positions in the causation chain. The final step is the use of causation models in scenario and policy analysis: once quantitative relationships are established among variables at the high end of the causation chain, and variables at the low end of it, the resulting model can be used to

[9] For a summary of projects funded by the GEF, see(Global Environment Facility, 1997).

simulate impacts on the latter of variation in values of the former, be those induced by policy decisions, or by exogenous processes outside the control of the decision makers.

The conceptual path described by Figure 1-4 is more of an idealized picture of what it would be desirable the process of analysis looked like, than a summary of efforts actually undertaken in the literature. Many studies (e.g. (McNeely, Gadgil et al., 1995; World Resources Institute, 1992) concentrate on analyzing the causes of loss, providing classifications and hierarchisation based on historical or thematic approaches, which more or less follow the simplified structure of block A in Figure 1-4. The difficulty of moving from block A to block B is the unavoidable consequence of the problem of defining in an uncontroversial way the diversity objective function, as discussed in section 1.3.2.1. Furthermore, it is also a reflection of the often limited scientific understanding of the immediate linkages between factors operating at the proximate level, and the actual loss of diversity (as reviewed in section 1.3.2.2).

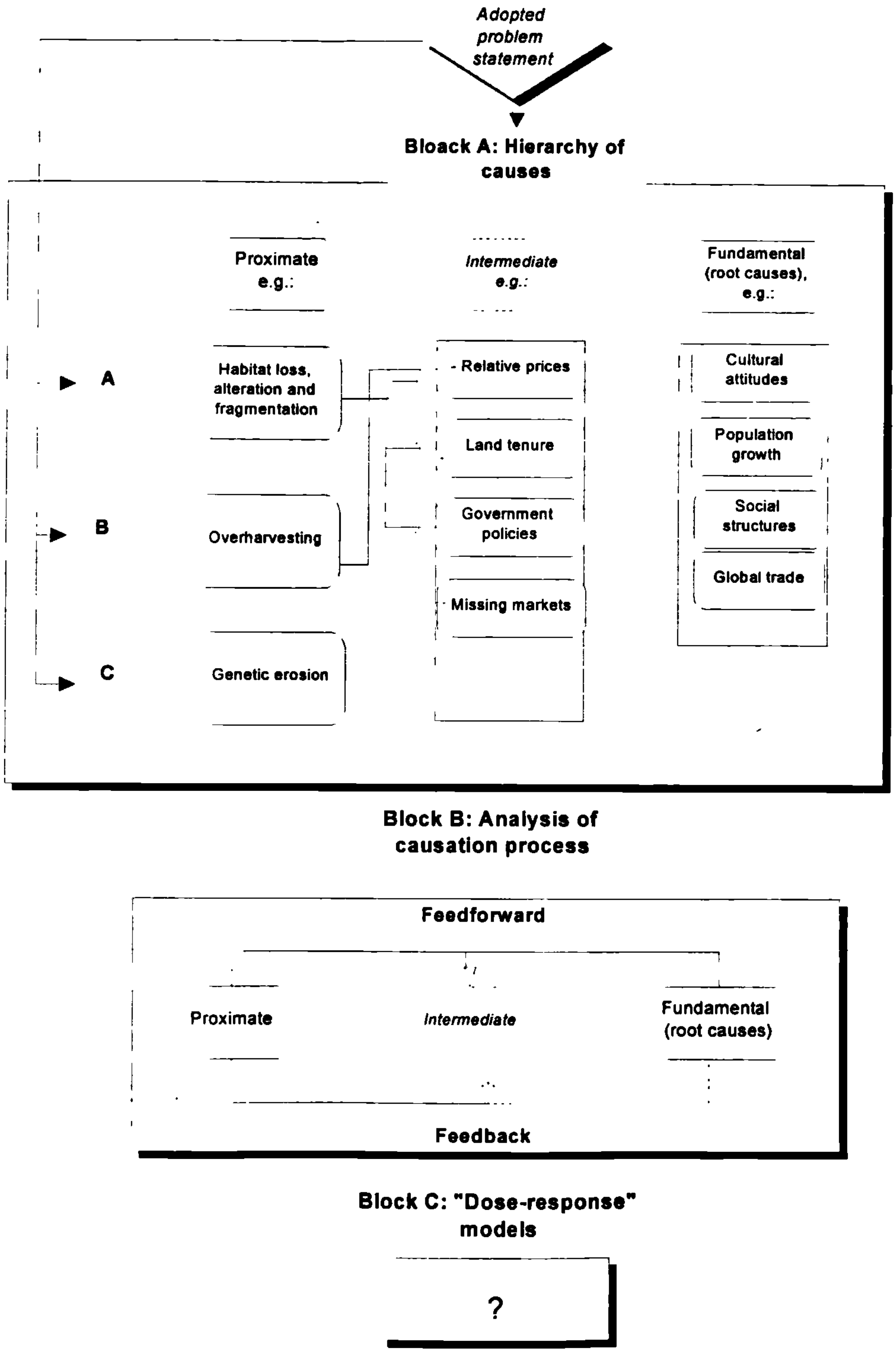

Figure 1-4: an "ideal" framework for analyzing the causes of biodiversity loss

1.4.1. Classifying the causes of biodiversity loss

Figure 1-4 proposes an "ideal" path for analysing the problem of diversity loss. As a great deal of attention been given in the literature to the material contained in block A, it may be worthwhile elaborating on some classifications of the causes of biodiversity loss (see Figure 1-5 for a graphical summary of the ensuing discussion). A first type of classification refers to the level at which biodiversity is being depleted. We can distinguish among depletion at the genetic, species, or ecosystem level. For example, species over-exploitation clearly operates at the species level, whereas forest conversion operates at the ecosystem level. Clearly, factors damaging ecosystems' balance will also imperil species' survival, whereas factors of stress on any given species will not necessarily affect ecosystems' equilibrium.

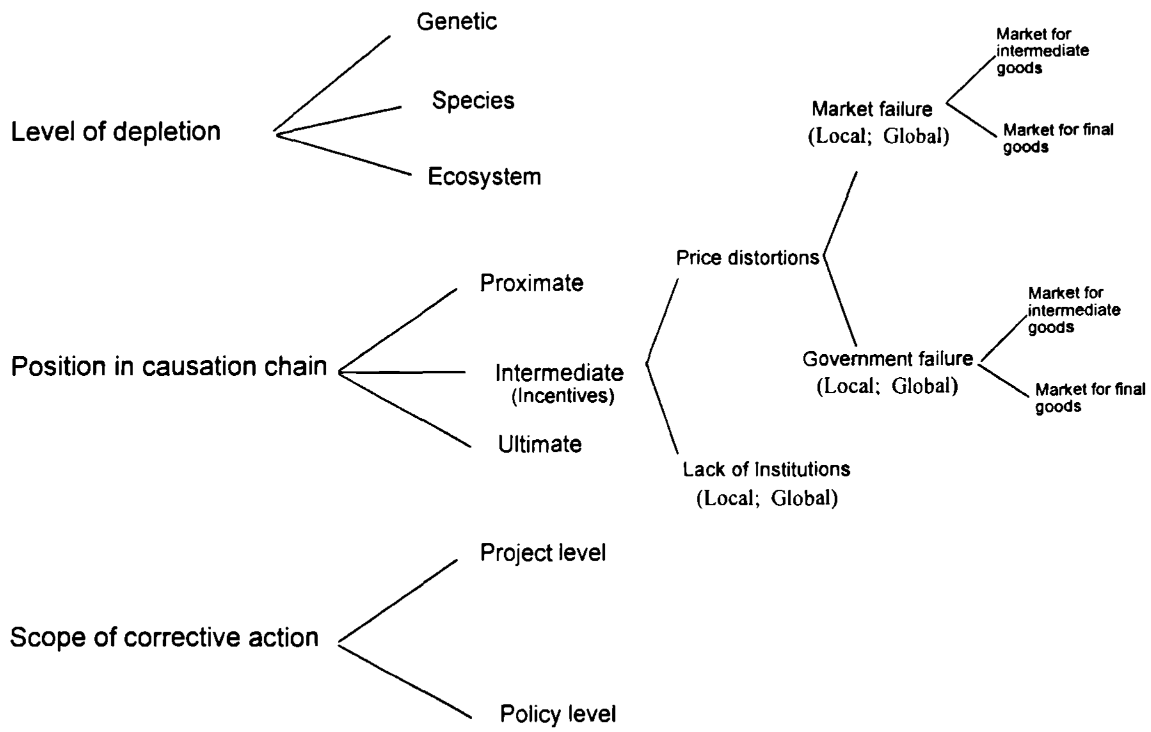

Figure 1-5: A taxonomy of causes of biodiversity loss

A second classification refers to the position of any given factor in the causation chain that leads to biodiversity depletion. We can define proximate, intermediate and ultimate causes.

i) Proximate Causes

Human action, or natural phenomenon induced by human action, which are directly responsible for biodiversity depletion. Causes belonging to this group include: species over-exploitation; introduction of exotic species; land conversion; soil erosion and desertification.

ii) Intermediate Causes

Incentives which induce proximate causes, i.e. activities directly leading to biodiversity depletion. In some cases, depletion incentives are produced by inadequate functioning of the price mechanism, like in the case of prices not reflecting the cost in terms of biodiversity loss of some production practices (e.g. conversion of land to agriculture; ecologically unsound agricultural practices; water or air pollution).

In some other cases, disincentives to conservation are the result of the lack of information, institutions and resources which could allow sustainable management of biological resources. Knowledge of ecosystems' value in terms of their life-support functions may be inadequate, both among the generic public, and among policy makers (information failures). Even if there is private and public awareness of the importance of conservation, the required institutions, and the necessary endowment of material and human capital may not be available. Among the missing institutions, a special importance is traditionally given to absent or ill-defined property rights on land, or on natural resources like water, forests, air.

Note that even if sometimes the lack of information and institutions may be explained in terms of price distortions (building institutions required for, say, industrial development has a higher pay off than institutions supporting ecosystems protection), the phenomenon will in general have more complex social and cultural roots.

iii) Ultimate Causes

These are the causes ultimately responsible for generating social and economic incentives which do not favour conservation. Several authors agree in singling out a few number of key causes: human attitudes towards natural resources, population growth, natural resource consumption patterns, global trade, inequitable distribution of income and wealth, global institutional and market failure (World Resources Institute, 1992; McNeely, Gadgil et al., 1995).

Population growth coupled with low standard of living increase the pressure on natural resources. Vested interests and pressure groups at the local and national level often hinder the adoption of conservation measures, and impede the correction of those price distortions from which they benefit.

The lack of appropriate international markets and institutions prevent the international community from expressing to developing countries its willingness to pay for enhanced conservation, and does not allow the necessary transfer the of human, financial, and technological resources.

Finally, historical patterns of unbalanced development make developing countries less willing to accept modifications in their exploitation of natural resources before reaching a standard of living comparable to those enjoyed by developed nations.

Eradicating the ultimate roots of biodiversity loss will probably sound as the most successful avenue towards conservation. Unfortunately, in many cases it is the most problematic and least viable approach. First, it is quite frequent that many if not all of the ultimate causes listed above are present at the same time. The simultaneous presence of high rates of population growth, low or declining standards of living, strong social and political pressure groups is a distinguishing feature of many developing countries.

Second, interventions which aim at modifying the distribution of power among social groups, or at altering demographic patterns are the least likely to be viable and politically acceptable, at least in the short-medium term.

These difficulties suggest that even if tackling the ultimate causes may in theory be the most effective solution, a more gradual and realistic approach would be to deal with the intermediate causes. It may therefore be useful to consider two additional classifications of those causes.

Intermediate causes are identified here with depletion incentives. The existence of these incentives may be due to market or to government failures. Market failures occur because market prices do not normally reflect external costs of individual actions, like depletion of biodiversity. In the second case, government may alter the "natural" relative profitability of alternative uses by making disruptive activities, like land conversion, more attractive than conservation. There is substantial evidence on the effect of tax and credit subsidies to agriculture on deforestation and land conversion[10].

The above examples refer to market and government failures taking place at the local level. Both however can also occur at the global level. Biodiversity generates global benefits, which are reflected in existence or option values of conservation. If there are no markets where the international community could express its willingness to pay for conservation, and if there are no mechanisms enabling governments to take collective actions, then we are in presence of global market and government failure. Notice that, more generally, the absence of instruments co-ordinating individual and government actions at the global level could be conceived as a lack of global institutions.

Furthermore, price distortions can operate in markets for intermediate or final commodities. This distinction is important because of the technological constraints that may be imposed on conservation measures. Suppose that in producing a given commodity, a technology is being used, which harms biological resources (e.g. a factory which pollutes air or water nearby a forest area). Alternative technologies may not be available in the short-medium run, because of lack of know-how or human capacity, because of capital constraints, or because of high sunk costs associated with investments in the polluting technology.

In this case, interventions at the policy level in the form on a tax on the polluting technology may not have for a long time the desired effect of encouraging the adoption of the alternative technology. At the project level, technological rigidities may make projects involving cleaner technologies not viable altogether.

A final classification refers to the scope of the action needed to correct the cause of biodiversity loss. In some cases, it may be sufficient to take measure at the local level, like establishing a protected area in an area subject to encroachment. These interventions take place at the *project level.* In some other cases, a wider scope of intervention will be

[10]For overviews on the effect of tax and credit policies on environmental degradation see (Pearce & Warford,

required. Measures like removing policy distortions, or modifying the land tenure regime, will have region- or economy-wide effects. In this cases, we are in presence of measures taken at the *program* or *policy* level.

Discussion

This section has reviewed the conceptual issues associated to developing a framework for analyzing the process of biodiversity loss, as well as discussed factors at various levels in the hierarchy of the causation process.

There are a number of reasons why the study of the causes of biodiversity loss has had so far limited usefulness for policy and management purposes. A first one is the controversial definition of biodiversity objectives. A second reason is the dearth of models establishing quantitative relationships between human-induced causes and biodiversity effects. Some authors highlight the inherent complexity of developing quantitative models of human interactions with the global environment, due to complicated interdependencies, non-linearities, irreversibilities, time lags and the interplay of variables at the local, national and global scale(Stern, Young et al., 1992)[11].

The limits to the current understanding of the process of biodiversity loss suggests that theoretical and applied research may have an important role to play. Given the importance attached by the ecological and biological literature to habitat modifications, this dissertation focuses on social and economic processes that determine land use decisions. Chapter two analyses the sequence of land use changes typically observed in a number of tropical countries, and discusses interventions which could alter the incentives for land conversion. Based on case study material in Mexico, chapters five and six propose quantitative models for analysing land use decisions at the farm level, and for their aggregation over space and time.

1993; Swanson & Cervigni, 1996; Repetto & Gillis, 1988)

[11] Quoted in (Stedman-Edwards, 1997). This would be an argument for preferring the development of verbal, qualitative, or diagrammatic models to quantitative ones(Stedman-Edwards, 1997). However, it may also be argued that an excessive use of qualitative models for policy interventions may broaden, rather than narrowing it, the scope for arbitrariness in public decision making. A third reason is the scarcity of data of both ecological and socio-economic nature required for improving the understanding of the loss process.

1.5. Economics and biodiversity: bref review of the literature

There are some special features of biodiversity that make it an obvious candidate for economic analysis. These include the difficulties of defining it, the uncertain consequences on human welfare of its reduction, the irreversibility of its loss, its nature of an international public good.

Historically, however, it is only in recent years that the economic literature has focused on the actual concept of (and term) biodiversity. Earlier debates have addressed issues that can be considered parts of the broader problems. A first strain of papers are concerned with revisiting the principles of benefit - cost analysis (BCA) for decisions that may entail the irretrievable lost of natural areas as a result of development.

Building on previous work on conservation (Krutilla, 1967) and on capital theory (Arrow, 1968), (Fisher, Krutilla et al., 1972) show that the simple presence of irreversibility makes the case for less development; and that this result is strengthened if benefits from preservation are increasing over time, relative to benefits from development. Explicit modifications of standard BCA decision criteria are proposed by (Porter, 1982), when projects consist in developing a natural area and converting it to alternative uses, like industrial or agricultural activity.

A formal treatment of the nature of the conservation problem in presence of irreversibility is provided by (Arrow & Fisher, 1974) and (Henry, 1974). The most important feature of this branch of the literature is to take explicitly into account the one aspect of the conservation problem that, in addition to irreversibility, makes it so intractable for decision makers. That is, the information asymmetry between the preservation and development choices: while development benefits are, subject to reasonable approximation, known with certainty, preservation benefits are in most cases uncertain.

Yet, as it is shown in subsequent contributions[12] that refine the basic ideas of Arrow, Fisher and Henry, it turns out that, under a set of assumptions about the features[13] of the decision

[12] See (Fisher & Hanemann, 1986) and (Hanemann, 1989).

problem, it is the very presence of uncertainty and irreversibility at the same time that makes optimal development lower than in standard situations (i.e. situations with no uncertainty and irreversibility).

The key concept that supports this result is quasi-option value. This is defined as the expected value of information, *conditional* on the decision of not developing in the first place. For the class of decision problems studied by Arrow, Fisher and Hanemann, quasi-option value is non-negative, which implies that there is always a non-negative gain (i.e., there is never a loss) attached to the choice of postponing development until more information is available on the benefits from preservation.

In addition to quasi-option value, there have been other approaches that advocate conservative revision of criteria to be adopted in development decisions. The Safe Minimum Standards (SMS) literature (Southgate, 1991) uses methods of decision theory (in particular the MiniMax criterion) to justify avoidance of decisions that lead to irreversible consequences (such as species extinction) "unless the social cost of doing so are unacceptably large".

In the area of environmental law and regulation, the "precautionary principle" has been often championed as the appropriate way for the environmental regulatory community to deal with the problem of uncertainty. The principle states that rather than await certainty, regulators should act in anticipation of any potential environmental harm in order to prevent it (Costanza, 1994).

One thing is to warn about extinction, another thing is to explain it. In parallel to the debate about appropriate decision making rules in presence of irreversible effects provoked by development, a separate branch of the literature has focused on the economic analysis of activities that lead to the extinction of species. The seminal work in this area (Gordon, 1954; Clark, 1973; Clark, 1973) focuses on fish extinction due to overharvesting. In Clark's

[13] In particular, a) only two periods are considered; b) in both of them, there are only two discrete choices: either no development or full development; c) new information is obtained by preserving, *and not* by developing.

analysis, overharvesting may occur under two different assumptions about the prevailing property right regime.

Under open access to fish stocks, the harvesting equilibrium will be determined by the "zero rent" condition, (and not by the "zero marginal rent" condition that an individual, profit - maximizer stock owner would select). If the harvesting rate corresponding to the zero rent point exceeds the Maximum Sustainable Yield (MSY) harvesting level, the stock will be depleted to extinction.

Extinction can also occur under private ownership if the growth rate of the species stock is lower than the single owner's discount rate. If the "rate of return" to the resource (i.e. the resource's growth rate) is less than the interest rate (discount rate, opportunity cost of capital and interest rate are all equal here), it will make sense to "mine" the resource to extinction, and invest the proceedings in higher yielding assets in the capital market or elsewhere.

One of the policy implications of Clark's model is that for low growth species, the higher the market price, the higher the likelihood of extinction. Therefore, policies aimed at conservation need to lower the resource's sale price. A theory of extinction that reaches opposite policy conclusion has been proposed by Swanson (Swanson, 1994; Swanson, 1990).

A key feature of Swanson's theory is to highlight that resource management decisions are taken not only on the basis of the net return to the resource's use, but also on the basis of the opportunity cost, i.e. the return to alternative uses of the resource. While this observation may have little bearing on marine environments that have few alternative uses, it makes a significant difference when it comes to land-based species: land has a number of alternative (and often mutually exclusive) uses.

If the opportunity cost of maintaining an area in a wilderness state (i.e. the foregone revenues from agriculture or urban development) are high, it will make sense for the resource user or manager, to give up the land use with lower returns. The policy implication is that species will survive only if activities compatible with their conservation command high enough returns to compete with alternative land uses.

The proliferation of the economic literature on the general problem of biodiversity (as opposed the more specific topics of land conversion or species extinction) has been fostered by a number of factors. One is the international political and policy process leading in 1992 to the UN Conference on Environment and Development, and to the signing of the Convention on Biological Diversity.

At the academic level, another important factor was the increasing attention given by of economists to interdisciplinary approaches that highlight the fundamental support function provided by ecosystem to social and economic system(Barbier, Burgess, and Folke, 1994). "Ecological economics" (Costanza, 1991)is being proposed as a new discipline, separate both from economics and ecology, and championed as the paradigm for understanding the interlinkages between natural systems and human activities.

A first set questions asked by economists in the context of this generation of studies on biodiversity concerns the compatibility between market-based resource allocation and the maintenance of natural systems' life support function. Making use of notions borrowed from ecological theory,(Perrings & Pearce, 1994) argue that the existence of thresholds (around which complex ecological systems become discontinuous) alters profoundly the economic theory of the instruments for pollution and resource use control, and warrants re-examining the merits of quantity based instruments, such as standards, normally dismissed by the conventional theory as inefficient.

A second set of studies addresses the fundamental question of measuring diversity. As argued in earlier sections, the issue is a particularly important one, given the multidimensional nature of the problem encapsulated in the phrase "biological diversity", and the difficulty of drawing policy responses to a problem that is not defined clearly in the first place. There have been a few attempts at formulating a measure of diversity of any give collection of species. The common starting point is the definition of a measure of dissimilarity, or distance[14], among single pairs of species. The way in which the measure of

[14] The measurement of pair-wise distance is often based on genetic methods, such as DNA-DNA hybridization.

diversity of the entire collection of species is defined depends on the way the pairwise distances are aggregated. Two approaches have been proposed (Pemberton, 1996).

The first one (Solow, Polasky et al., 1993) is based on the distinction of the original set of species in two subsets, one comprising the (potentially) extinct species, and the other comprising the surviving species. The preservation-diversity (PD) measure is (minus) the sum of the individual distance of the extinct species form the set of the surviving ones. If no species goes extinct, the index is equal to zero. The biodiversity management problem can then be easily formulated as one of maximizing the PD measure (i.e. making it as close as possible to zero) subject to a fixed conservation budget.

The second approach (Weitzman, 1992) does not take into account the set of extinct species, but only the set of existing ones. Given a set of species, Weitzman defines its measure of diversity as the length of the tightest or most parsimonious feasible reconstruction of the set, in the sense of being the minimal number of steps required to account for its evolution. The so called "pure diversity" measure is the solution to a dynamic programming recursive problem in which a function of the point-to-set distance measure is being maximized.

Measuring biodiversity does not necessarily imply valuing it. Valuation is an indispensable (and often missing) ingredient in decision making about conservation and use of biological resources. It is necessary because devising mechanisms for internalizing externalities of biodiversity entails knowledge of the function describing the marginal social cost of its depletion, or the marginal social benefit of its conservation.

Valuation is often lacking or insufficient in actual decision making processes (especially in developing countries), due to both a) complex conceptual problems related to defining biodiversity and applying to it methods for measuring preferences not revealed in the market place; and b) data limitations. Prompted by advances in the theory and econometric practice of welfare economics and evaluation of environmental and other non-market goods (Johansson, 1987; Freeman, 1984; Mitchell & Carson, 1989), a growing volume of literature has been developing over the last decade. This literature, which can not be discussed here, has recently been comprehensively reviewed by (Pearce & Moran, 1994).

Chapter 2

Biodiversity loss, land use change and economic analysis

Given the importance attached by the ecological and biological literature to habitat modifications as a threat to biodiversity conservation, it is important to analyze the social and economic processes that determine land use decisions. This chapter analyses the sequence of land use changes typically observed in a number of tropical countries, and discusses interventions which could alter the incentives for land conversion.

2.1. Biodiversity loss and land conversion

There is abundant evidence suggesting that land use change phenomena are widespread world-wide. Many developing countries in Asia, Africa and Latin America host the remains of primary forests and other pristine areas especially rich in diverse biological resources. In those continents, conversion of land to productive activities like agriculture, pasture and other uses is particularly relevant, as summarised in Table 2-1.

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Table 2-1 Evidence on land use changes world-wide (Source: [World Resources Institute, 1992]).

	Cropland 1987-89	Percentage change since 1977-79	Permanent Pasture[a] 1987-89	Percentage change since 1977-79	Forest and Woodland[a] 1987-89	Percentage change since 1977-79	Other Land[a] 1987-89	Percentage change since 1977-79
World	1,477,877	2.2	3,322,943	0.1	4,095,317	-1.8	4,232,737	1.0
Africa	186,392	4.4	890,899	0.5	686,284	-3.6	1,200,565	1.9
North Central America	273,816	1.1	368,631	3.1	715,415	1	779,838	-2.5
South America	141,578	10.9	477,863	4.1	895,692	-4.6	237,792	4.7
Asia	454,456	0.8	694,251	-0.3	538,855	-5.3	1,043,666	2.8
Europe	140,409	-1.3	83,177	-4.0	156,851	1.1	92,524	3.8
USSR	231,871	-0.2	371,500	-0.6	945,000	1.7	678,829	-1.9
Oceania	49,355	11.6	436,622	-3.1	157,221	-0.6	199,523	5.0

[a]All figures in thousand hectares

Much of the literature focuses on the role of conversion of land from a pristine state to productive activities as a major proximate cause of loss (see for example (Groombridge, 1992; Lugo, 1988; McNeely, Gadgil et al., 1995). The theoretical rationale for this is provided by the island bio-geography theory (Mac Arthur & Wilson, 1967).

According to this theory, there is a more or less stable functional link (the species-area relation) between the extension of an area biologically homogenous and the number of species resident therein. The form of the species-area relation commonly adopted is $S = \alpha A^{\beta}$, where S is the number of species, A is the size of the area, and α and β are, respectively, a proportionality and an elasticity parameter. The latter is empirically estimated to range in the interval 0.15-0.35. In particular, with a value of β of approximately 1/4, a 90% reduction of the size of an "island", say forest, should produce a halving of the number of species.

There are at least two problems with estimates of species of loss based on the species-area relation; these problems are associated with the A variable, and with the α parameter, respectively. Looking at A, first, how does it change over time? What is an appropriate measure of the "island's" size that ought to be considered in the calculation? Consider the case of tropical forests, which are among the richest areas of the world in terms of biological resources.

Predictions of future extinction depend crucially upon assumptions about deforestation rates; as usual in this cases, simple fitting of a regression curve on past deforestation data may or may not be appropriate, depending on the way demographic, economic and policy variables are supposed to affect deforestation.

Furthermore, it is commonly asserted that the size of tropical "islands" should decrease when deforestation is taking place. However, it is often argued that there are not only two possible states of the land, i.e. forested and deforested land, but more than that. In particular, not all the logged forest has to be considered unforested land, since a part of it turns into secondary forest fallow; moreover, a proportion, even if small, of cleared land is converted every year into secondary fallow forest through natural regeneration or human intervention (Lugo, 1988)[1].

A further reason why species-area curves may overestimate extinctions is that these curves are based on single taxa, and it is likely that assemblages of species will exhibit different relationships which can not be captured by simply adding up curves (Lugo, Parrotta et al., 1993).

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[1] The role of second growth regeneration in mitigating the impacts of deforestation is questioned by some analyst: (Myers, 1994)notes that abandonment of cleared land, which is required for regeneration, is rare in much of West Africa, East Africa, and Sourhern and Southeast Asia, where population pressures are greatest. However, quoting (Browder, 1989), he concedes that in the Brazilian Amazonia in 1988, between 20 and 40 percent of deforested lands were starting to feature secondary forest recovery.

Consider now the α parameter in the species-area relation. This represents a scale factor on which the unit effect of size variation is applied, so that the overall effect on the number of species can be derived. If we interpret the S variable as the proportion of species resident in the island relative to the total number of species in a wider geographic region, say the tropics, as a function of the size of the island, a becomes the ratio between the number of species initially existing in a given "island", and the total.

It is the case that such a ratio exhibits wide variation across different types of habitats; there is evidence, for example, that species richness doubles from dry to moist forests, and triples form dry to wet forests. To quote again Lugo (1988), in estimating extinction rates, it should not be assumed "that all tropical forests are subject to the same rate of deforestation, respond uniformly to the same reduction in area, or turn into sterile pavement once converted".

Despite the fact that the documented evidence of species extinction through deforestation or other forms of land use change, is limited, there is consensus that habitat loss causes several species to be "committed to extinction". However, the time to reach a new equilibrium characterized by lower species number is unknown (McNeely, Gadgil et al., 1995). The species-area relationship (SAR) indicates a correlation between size of an area and number of species to be found in that area. However, accurate quantitative predictions of extinction should be based on models incorporating the known mechanism of extinction" (Barbault & Sastrapradja, 1995).

Subject to these qualifications, the island bio-geography theory, together with the empirically ascertained relevance of land use changes, still provides powerful arguments for being concerned about land use change. It is therefore necessary to analyse more closely the process of land conversion. This could be helpful in proposing interventions at the national and international level to mitigate this important cause of biodiversity loss. In what follows, the problem will be addressed, of what measures should be taken to prevent land conversion. It will be assumed that the geographical areas where interventions is warranted have been identified on the basis of some proper ecological or biological criterion.

2.2. A conceptual framework for addressing the problem of land conversion

As reviewed in chapter one, recent theories of extinction are based on an analysis of the allocation of land among competing uses (Swanson, 1990; Swanson, 1994). These theories are consistent with the basic postulate of economic theory, that resources are allocated among competing uses in such a way that economic returns from them could be maximised. Allocation of resources among land uses should be no exception. Accordingly, standard land use theory (as illustrated for example in (Hartwick and Olewiler, 1986), and (Randall and Castle, 1985) suggests that land use decisions are guided by the criterion of maximising W, the net present value of activities carried out on land over the relevant time horizon:

$$W = \int_{t_0}^{T} e^{-\rho t} \left(R_h(t) \right) dt \qquad \textbf{(1)}$$

where t_0 and T are the initial and terminal point of the relevant time horizon, ρ is the discount rate, $R_h(t)$ is the total of rents in the parcel of size h in time period t.

Rents, i.e. the revenues from land in excess of the input (labour and capital) cost, vary not only over time, but also across different land uses: agriculture (and within agriculture across different crops), ranching, logging, and so forth. The reason of this variation is that each use is characterised by different input requirements, and hence different labour and capital costs per unit of output, different price of the final output, and finally different transportation costs, depending on the distance from the market of the area where the activities are carried out. For use ***i***, rent is then defined by:

$$R_i = y_i \left(p_i - wl_i - t_i x \right) \qquad \textbf{(2)}$$

where

R is rent per unit of land (rent per unit of output, in brackets, times output per unit of land, ***y***);

p is price of the output;

t is transportation costs per unit of distance;

x is distance of the production site from the market;

l is the labour requirement per unit of output;

w is the wage rate.

This simple formulation assumes that there is a fixed input proportions technology, that capital inputs are limited to transportation capital, and that neither unit transportation costs, t, nor fertility (output per unit of land, y) vary with distance. In what follows, the analysis of the incentives to land conversion will be mainly referred to developing countries' frontier regions between agriculture and pristine areas. In those situations, the adoption of traditional production techniques is quite widespread, and access to alternative techniques pretty much constrained by institutional, financial and cultural factors. This justifies the assumption of a fixed factor proportion technology.

It is interesting to emphasise the last determinant of cost (i.e. distance) for three reasons. Firstly, because we are interested in the balance between developed and undeveloped (forested) land. When productive activities take place in locations further and further away from the market, the frontier between cleared and forested land moves ahead, and the size of the forested area shrinks. So, increasing distance from the market of activities requiring land clearing is a proxy for decrease in conservation.

Secondly, unit transportation cost is a parameter which can be influenced by policy through road building; therefore, policy can in some cases have a crucial role in determining land use changes[2].

Thirdly, we can use a diagrammatic tool known as "bid-rent function", which has the advantage of a very intuitive interpretation. Consider Figure 2-1: the variable X on the horizontal axis represents distance from a hypothetical market central location; on the vertical axis there are rents from land. The two downward sloping lines are the graphical counterpart of equation 2 for two possible competing land uses, 1 and 2.

For distances in the interval $[0, x_1)$, land will be used for activity 1, as rents from that use are higher. For distances in the interval $[x_1, x_2]$, land use 2 will prevail. For distances $x>x_2$, none of the two activities is profitable, and land will be left idle. The bid-rent function tells us what pattern of land use will result from maximisation of rents; in Figure 2-1, the bid-rent function is given by the line ABx_2.

[2]Indeed, this has seemed to be the case in the Amazon (see, for example, [Mahar, 1989], [Schneider, 1992]).

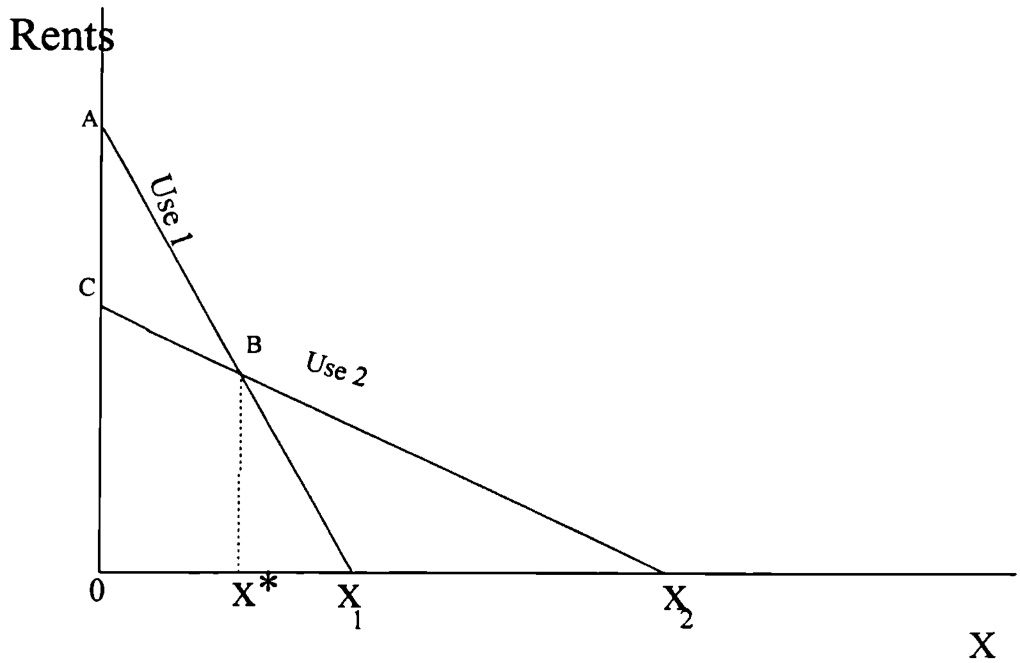

Figure 2-1 Bid-rent schedule for two competing land uses

The bid rent function could be used to conduct a very simple diagrammatic analysis of a pattern of land use change typically occurring in areas with relative abundance of pristine (mainly forested land), and undergoing a process of colonisation. This pattern is known as the "peasant pioneer cycle", and consists of a number of stages including logging, mineral extraction and/or annual cropping, ranching, and, as a possible but not inevitable last stage, abandoning land in favour of other, still virgin areas, where the cycle restarts. In this sequence, given relative abundance of land with normally undefined property rights, capital and labour are employed to a great extent to "mine the nutrients" contained in the forest's soil, rather than being invested in maintaining the soil productivity. This phenomenon is often summarised by the phrase "it is cheaper to bring the farm to the nutrients, than to bring the nutrients to the farm". In recent times, the pioneer cycle has been convincingly used by (Schneider, 1992) to explain deforestation in Brazil's Amazon.

Consider the four panels of Figure 2-2. They are meant to be only an example, useful to clarify ideas, but without claims of complete realism. In panel 1, an area is covered entirely by forest over the tract $0-\bar{x}$. Until distance x_e extractivism (i.e. sustainable harvesting of non-timber forest products), which does not imply clearing, is profitable; for $x>x_e$ no activity is viable, and the forest is left in its virgin state.

Agriculture has a lower labour input requirement (higher vertical intercept), but much higher transportation costs (few roads are initially available) than extractivism. The reason for this assumption is that in the case of agriculture, transportation costs have a more substantial component of input transportation cost (pesticides, irrigation, technical assistance and so on). As a result, agriculture it is more profitable only in proximity of the market, i.e. in the interval $[0, x_a]$, in which there are incentives to deforest. The bid-rent frontier is ABx_e.

In panel 2, a road building program has taken place. This has relevant implications for the slope of the rent functions. Namely, it tends to decrease transportation costs, that is, to make the rent curves flatter. However, it is likely that agriculture will benefit more from the road building program, so that its horizontal intercept will shift rightwards more (from x_a^0 to x'_a) than what the extractivism rent curve will do (from x_e^0 to x'_e). The new bid-rent function is now ADx'_e, so that it will pay to convert land to agriculture (and to deforest) in the interval $[0, x_1]$ (note that to keep matters simple, deforestation costs are deliberately ignored).

In panel 3, the fall in agriculture's productivity - due to nutrient mining - is represented by means of an increase in labour input requirement per unit of output, that is, a lower vertical intercept of the rent function. This has the effect of making profitable another activity with higher transportation costs (say ranching, or cultivation of a different type of crop), in the interval $[0, x'_1]$. Agriculture is now confined to the interval $[x'_1, x_1]$. Note that as deforestation has been carried out over the range $[0, x_1]$, the rent function for extractivism is no longer drawn for that tract. The bid-rent line is now $BGJHx'_e$, with a jump at J.

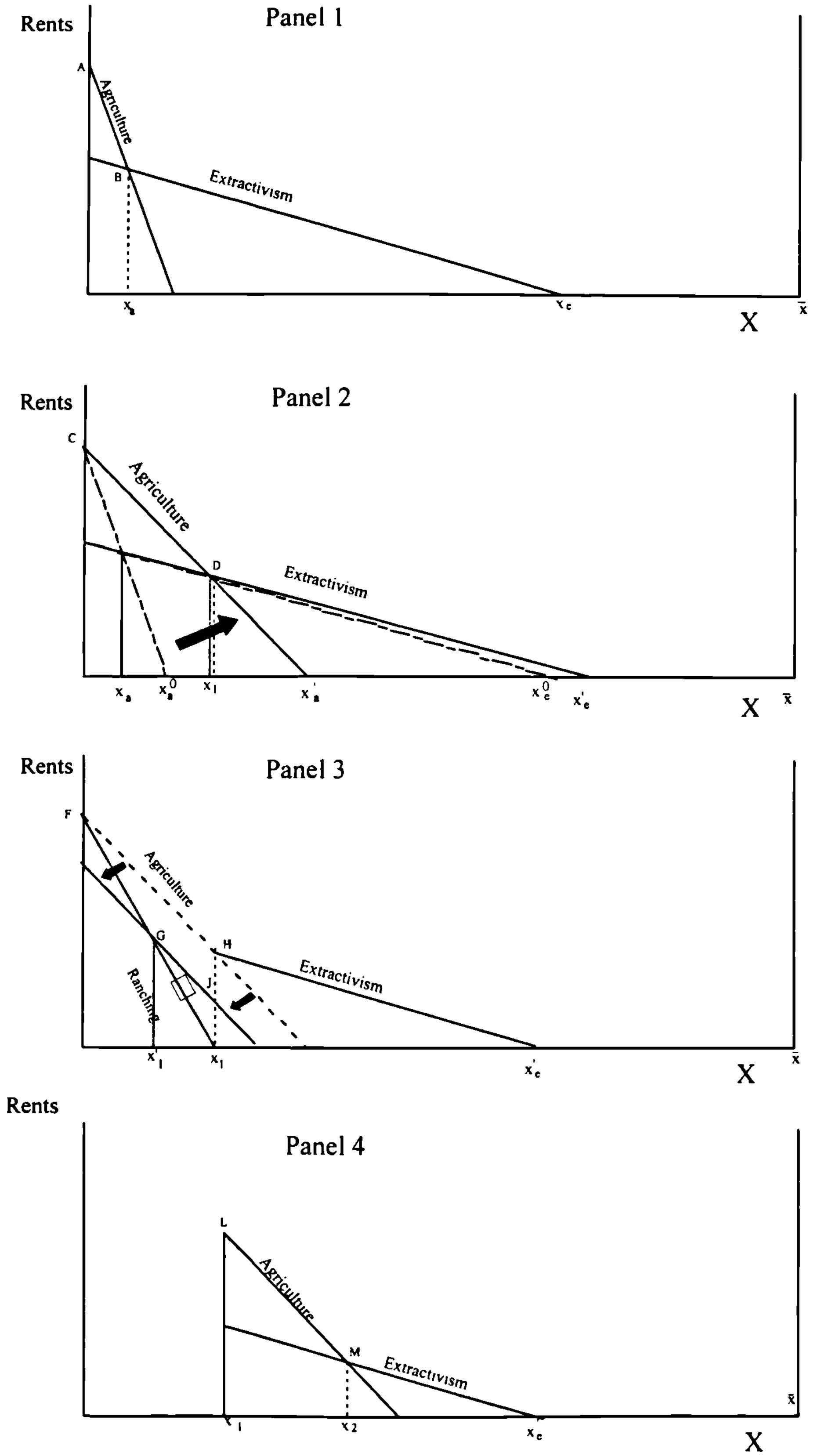

Figure 2-2: Frontier Expansion in a Bid-Rent Function Approach.

Consider now panel 4. Nutrient mining continues in the cleared area, so that both farming and ranching productivity decline; when they approximate zero, land is relinquished (interval [0, x_1]. In the meanwhile, population density has increased: road building and the prospect of rising income may have encouraged colonisation, or proliferation of urban agglomerates; cleared land may have become accessible to placer miners (like the Amazon's garimpeiros). These factors, in turn, increase demand for agriculture commodities, and, thus, with upward sloping supply, their price. In terms of the diagram, this has the effect of shifting the rent function upwards, so that new deforestation in the interval [x_1, x_2] is called for, and the size of the extractivist area shrinks to x'_e-x_2. Now the bid-rent line is LMx'_e. The process may iterate until extractivism ceases to be profitable and goes completely out of business, while the development frontier approaches $\bar{x}$.

2.3. *Interventions to alter the incentives to land conversion*

The very simplified framework of the rent-bid function captures some of the essential elements of the problem of land conversion: the competition among alternative activities for land use, and the impact of the various type of costs on land use patterns. In any particular area of interest for biodiversity conservation, a large number of productive activities will be possible, but they can be divided in two groups, conservation compatible activities (CC), like sustainable harvesting of timber and/or non timber forest products, agroforestry, or ecotourism, and non-conservation-compatible (NCC), e.g. shifting agriculture, unsustainable logging[3]. CC do not require land conversion, whereas NCC do. For simplicity, we will assume that all NCC and all CC activities can be aggregated in two groups. Rents accruing from NCC activities are represented by the r_1 function, whereas rents generated by CC activities are represented by the r_2 function (see again Figure 2-1 for an illustration).

It will also be assumed that the area of interest has just been made accessible, say by road building, so that in principle both land use options are open to private resource users. In

[3]Clearly, what activities could be included in each group will crucially depend on the definition of biodiversity that is being adopted. Under particularly stringent definitions of the 'diversity' objective function, few, if any, activities could be included in the CC group. In that case, the problem of avoiding land conversion is essentially one of imposing legal restrictions on land use, and establishing a protected status. The problem of the effectiveness of these restrictions will be addressed below.

the absence of any intervention, land users would find it profitable to convert land to NCC activities up to distance x^*. How would it be possible to avoid conversion in the interval $[0, x^*]$[4], i.e., to induce land users to carry out activity 2 in the entire area? In order to answer this question, it is necessary to understand what are the forces determining the divergence in the two rent gradients.

There are a number of reasons why NCC dominate CC over a relevant tract, i.e. $r_1 > r_2$ in $x \varepsilon [0, x^*)$. Summarising some of the aspects discussed above in the section on the causes of biodiversity loss, these are briefly reviewed below.

i) Policy Distortions

The first and most obvious reason of dominance of NCC activities is that the associated returns may be artificially inflated by policy interventions. If activity 1 is agriculture, subsidised credit or fertilisers purchase have clearly the effect of reducing input costs, shifting the r_1 function upwards, and encouraging more land conversion than it would be otherwise the case. Removing policy distortion would shift r_1 downwards, and reduce the gap with the r_2 function.

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[4]Note that when a process like the pioneer sequence is in action, conversion will take place initially only in the tract $[0, x^*]$, but it will successively affect a much larger area.

ii) Property Rights

Another usual explanation of the observed pattern of land conversion is the absence of property rights. Consider the case of land formally claimed by the state, but subject to an open access regime. Farmers willing to expand cultivation face at most the cost of clearing and converting land to agriculture. If they were to expand cultivation on parcels of land with clearly defined property rights, they would have to pay a rental fee to the legitimate owner; or if the latter were to cultivate the land himself, he would have to impute some costs in terms of foregone rental value to the agricultural activity carried out. Obviously in presence of formally defined property rights, a rental cost should be imputed to CC activities as well. But so long as $f_1>f_2$, where f_i is the rental cost from activity i, less land conversion would take place than in the open access regime[5].

iii) Yield decline

This type of factor has particular relevance in dynamic settings. In many tropical areas, traditional cultivation technique lead to a rapid decline in the soil's nutrient content, and hence to a drop in yields per hectare. When yield decline, and no other source of cash income is available, farmers may need to convert new land to cultivation. They will do so if the cost of conversion is lower than the cost of investing in soil conservation

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[5]See (Southgate, 1990) for a more formal treatment of the effect of property rights definition on frontier expansion.

techniques. The latter cost, in turn, may be raised by market imperfections like credit constraints.

iv) 'Fundamental' difference in returns

In all of the above cases, NCC generate higher returns due to some form of market or institutional imperfections, like policy distortions, ill-defined property rights, or credit constraints preventing the adoption of soil conservation techniques. It may be the case that even removing all these distortion factors, a fundamental imbalance in the relative returns of NCC vs. CC activities persists. The rest of this chapter will address the issue of how to generate incentive for CC activities when 'spontaneous' incentive would favour NCC activities. This issue is likely to be of interest to the International Community (IC): to the extent that biodiversity generates transnational externalities, IC might consider transferring resources to countries hosting biodiversity to improve the chances of conservation.

Two possibilities might be considered. a) IC might provide resource necessary for shifting the r_2 function upwards up to the point where no NCC activity is attractive to individual land users. b) IC might simply compensate land users for the opportunity cost of conservation, i.e. for the difference in rents in the region $x \varepsilon [0, x^*)$.

Before considering each of these two possibilities individually, it is important to note one common feature. In every scheme of biodiversity conservation, the international community is assumed to provide resources to be used for protecting biodiversity. The international community, however, can not use the funds itself to achieve the desired objective, but requires the co-operation of some counterparts in the country hosting the biological resources to be protected. These counterparts could be the national state, public authorities at the local level, or land users, acting in isolation, or possibly organised in a local NGO. These parties would have to administer the resources provided by the international community to increase the profitability of CC activities, or to distribute them among land users who would bear the opportunity costs of not converting land.

The international community has imperfect knowledge of some of the characteristics of its country counterparts. For example, it will not know exactly what are cost and benefits of activities which are currently carried out in the area to be conserved, nor will it know costs and benefits of suggested conservation compatible activities. (In terms of the preceding analysis, the international community will not know with certainty the location of the r_i curves).

Furthermore, the international community will not be able to monitor closely the behaviour of the counterparts. In particular, it may not be possible to monitor the state's investment in infrastructure enhancing the profitability of CC activities. All the international community may be able to observe *ex-post*, is the outcome in terms of changes in land use of its agreement with the state or with land users. This information, too, may not be completely reliable. For example, it is not always straightforward to acquire uncontroversial data on deforestation. Land reconnaissance may be costly, and the use of remote sensing techniques is often constrained by weather induced biases.

Even if the conservation outcome is easily measurable, it may not be possible to establish a one to one relationship between that conservation outcome and the 'conservation effort' of the party which has entered an agreement with the international community. For instance, land owners may refrain from carrying out NCC activities, and yet a high degree of land conversion may be observed due to the encroachment of squatters (and to inadequate state's effort to enforce legitimate owners' property rights)[6].

The following sections will illustrate two simple set-up to analyse the issue of transferring resources to a) increase the profitability of CC activities, and b) to compensate land users for the foregone benefits from land conversion.

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[6] All these considerations suggest that the problem of trading conservation between the international community and a domestic counterpart could be analysed in the context of principal-agent theory (see (Rees, 1985) for an overview). This theory deals with problems of choices which a subject, called principal, find advantageous to delegate to another subject, called agent. The principal faces uncertainty on the characteristics (adverse selection) or on the action (moral hazard) of the agent, and has the problem of devising a payment mechanism for the agent which optimally combines incentives to provide effort -given limited observability- with incentives to enter the contract, given risky outcomes of agent's actions. Occasional reference will be made to problem of uncertainty and limited observability, but a more complete analysis of the problem in terms of principal agent, which may well be the subject of a separate research, will not be attempted here.

2.3.1. Increasing rents from conservation compatible activities

In the very simplified version of the rent-bid function approach outlined above, the position of the rent-bid line is determined by two parameters: the slope and the vertical intercept. Equation 2 could be expressed as:

$$\frac{r_i}{y_i} = a_i - t_i x; \quad with: \; a_i = p_i - w z_i \qquad \textbf{(3)}$$

Rents per unit of output, r_i/y_i, are a direct function of a_i, the price margin over labour cost per unit of output, and, at any given distance x, an inverse function of t_i, the transport cost per unit of output.

As illustrated by Figure 2-3, activity 1 is profitable in $x\varepsilon[0, x^*]$, whereas activity 2 is only profitable in $x\varepsilon[x^*, a_2/b_2]$. The attractiveness of activity 2 will clearly change if the parameters a_2 and t_2 change. What is the combination of shifts in the slope and intercept of rent gradient 2 that would eliminate the incentives towards land conversion? A first possibility is to make activity 2 *everywhere* more profitable than activity 1. This would happen if the vertical intercept shifts upwards until a_1, while the horizontal intercept stays constant at a_2/b_2.

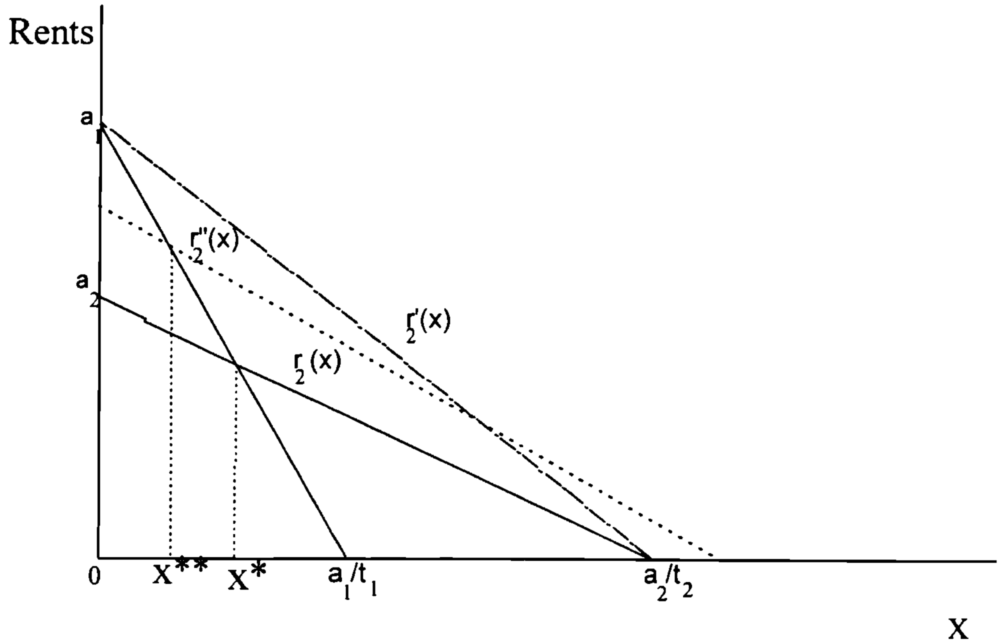

Figure 2-3 Increasing rents from conservation compatible activities

In Figure 2-3, the resulting rent gradient is given by $r'_2(x)$. However, this line lies everywhere above both r_1 and r_2, and therefore generates a larger amount of benefits than the initial case. The intervention to conserve biodiversity thus makes local communities better off[7]. The question then arises as to how should the rent gradient 2 shift in order to generate the same amount of benefits prevailing in the no-intervention case. That is, what is the incremental cost of the intervention *net* of domestic benefits?

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[7] In terms of the incremental cost analysis of chapter 3, in such an intervention there are incremental benefits that are not netted out from the resource transferred; i.e. the γ parameter is less than 1.

The total cost of intervention, C, will depend on the cost of raising the vertical intercept, that is the cost of increasing the price-labour cost margin; and on the cost of flattening the rent function, that is the cost of infrastructure investments to reduce transport cost: C=C(a,t). Assuming that the price of the output, p, and the wage rate, w, are not affected by the intervention examined, the only way to increase the margin is to reduce z=l/y, the labour requirement per unit of output. To simplify further, we can use w as the numeraire, so that the margin becomes a = p-z.

Rents prevailing in the no intervention case are the sum, ***M***, of the rents from activity 1 between 0 and x*, and of the rents from activity 2 between x* and a_2/t_2:

$$M = \int_0^{x^*}(a_1 - t_1 x)dx + \int_{x^*}^{\frac{a_2}{t_2}}(a_2 - t_2 x)dx = \frac{1}{2}\left[\frac{(a_1 - a_2)^2}{(t_1 - t_2)} + \frac{a_2^2}{t_2}\right] \quad \textbf{(4)}$$

The problem for the provider of the funds is to minimise the overall cost of the intervention, subject to the constraint that total rents deriving from the 'new' CC activity, r=a - tx, will be no less than 'old' total rents, M. The constraint can be expressed as:

$$\int_0^{\frac{a}{t}}(a - tx)dx \geq M \quad \Rightarrow \quad \frac{a^2}{2t} \geq M \qquad \textbf{(5)}$$

From the lagrangeian of the problem:

$$\Lambda = C(z,t) + \lambda\left(M - \frac{(p-z)^2}{2t}\right) \quad \textbf{(6)}$$

the first order conditions are:

$$\begin{aligned} C_z + \lambda\frac{(p-z)}{t} &= 0; \\ C_t + \lambda\frac{(p-z)^2}{2t^2} &= 0 \quad \textbf{(7)} \\ M - \frac{(p-z)^2}{2t} &= 0 \end{aligned}$$

Solving for the margin and for the unit transport cost one gets:

$$(p-z)^* = M\frac{C_z}{C_t}; \qquad t^* = \frac{M}{2}\left(\frac{C_z}{C_t}\right)^2 \qquad \textbf{(8)}$$

The second order conditions impose some requirement on the cost function[8]. Assuming a particular quadratic form for the cost function allows a simple graphic interpretation of the result. Suppose that the cost of changing any of the two parameters is given by the square of the deviation from the initial values, z_2 and t_2, and the that the two cost components are summed:

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[8]Assuming separability of the cost function, i.e. $C_{zt}=C_{tz}=0$, the bordered Hessian is given by:

$$\frac{-4C_t^2\left(C_t^3 + C_{tt}C_z^2 M + C_t^2 C_{zz} M\right)}{C_z^4 M}$$

$$C = (z - z_2)^2 + (t - t_2)^2 \qquad (9)$$

The cost function is then represented by concentric circles in the space (a, t), with total cost increasing on circles of larger diameter (see Figure 2-4). The original parameters z_2 and t_2 lie to the left of the shaded area where total rents are no less than M, as, by assumption, total rents under r_2 are less than M. The point of tangency between the iso-cost circles and the constraint line is the solution to the minimisation problem.

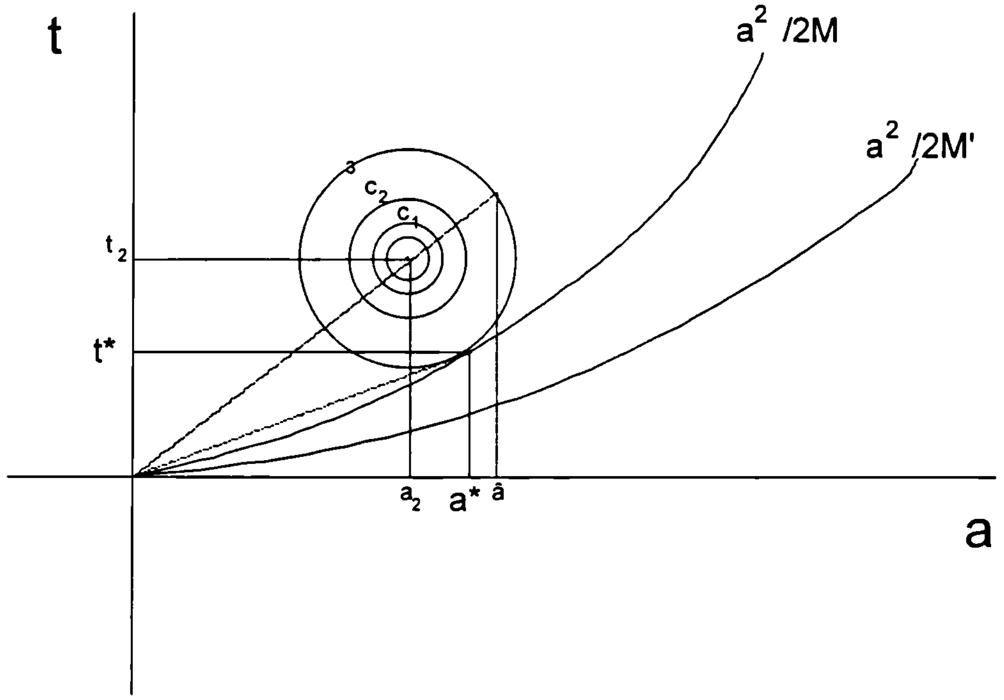

Figure 2-4 The solution to the rent-increasing problem

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which has to be negative for the stationary values to be a minimum.

The solution (a^*, t^*) generates the same amount of aggregate benefits of the no-intervention case at minimum investment cost, given the cost function C ($\cdot$). However, the rent bid function r_2'' generated by the (a^*, b^*) parameters will not, in general, be individually incentive compatible. Depending on the marginal cost ratio C_z/C_t, the new line will cross the r_1 line somewhere to the left or the right of x^*, i.e. the development frontier in the no-intervention case. Let us call this new 'frontier' x^{**}. Land users to the left of x^{**} will still have an incentive to convert, as $r_1 > r_2'$ in $x \varepsilon [0, x^{**}]$ (see again Figure 2-3).

However, this will not be the case if there is a single owner of land, be it a private individual, or a community which redistributes income among its members. In this case, the individual or the community will be indifferent between the situation with and without the intervention, as, by construction, the overall amount of rents is fixed at M.

If there are many uncoordinated land users, then r_2 will have to be more profitable than r_1 over the entire tract $[0, x_2]$, as in the case of the r'_2 function constructed above. Whether or not the 'individual' solution is more costly than the 'community' solution depends on the value of a_1. To see this, consider that imposing the requirement of a fixed horizontal intercept is equivalent to fixing the ratio a/t at a_2/t_2. This is represented in Figure 2-4 by the line joining the origin and the point (a_2, t_2).

The cost of the 'no-community solution' will be determined by the intersection between that line through the origin and the line $a=a_1$. There is only one vale of a_1 (assuming $a_1>a_2$) such that the cost of the two solutions is the same. This is given by $\hat{a}$, which is the solution of the couple of equations $C(a, t)=C^*$ and $a/t=a_2/t_2$, where C^* is the cost of the solution (a^*, t^*). That is, $\hat{a}$ is at the same time on the line from the origin with slope a_2/t_2, and on the iso-cost line identified by a^*. Figure 2-4 displays the location of $\hat{a}$. If $a_1>\hat{a}$, then the individual solution is more expensive than the community solution.

In the simple framework outlined in this section, the international community has the option of preventing land conversion by modifying the rent gradient of CC activities. It has been shown that under some circumstances, the cost of the intervention is lower if land is managed by a community which redistributes rents among its members, rather than being managed by uncoordinated individual users[9].

[9]An implicit assumption in this conclusion is that the community has the ability to monitor the behaviour of its members, and preventing land users residing in the tract $[0, x^{**}]$ from carrying out activity 1 *and* claiming a share of overall rents M.

2.3.2. Compensating foregone development benefits

In some cases the option of altering the pattern of relative returns of CC vs NCC activities will not be viable[10]. This may be so for various reasons. First, the cost of increasing rents from CC uses of land may turn out to be too high. This is likely to happen when activities like agroforestry or non timber forest products face very poor market prospects, very unfavourable soil or whether conditions, or when the required institutional infrastructure (e.g. extension, capacity building) is absent and very costly to establish from scratch. Another possibility could be that activities not requiring land conversion are in fact economically viable, but they are deemed incompatible with conservation. Many countries establish sanctuaries or biosphere reserve where no economic activity is allowed, apart from strictly controlled access for scientific or educational purposes.

In what follows, we will still consider the problem in terms of choice between two competing land uses. Again with reference to a rent bid function approach, the problem is how to deter conversion in the tract where this would be profitable, $[0, x^*]$ in Figure 2-3, given that the possibility of shifting the curves is now precluded. The answer is obviously

[10]Even if the option of changing the relative returns of NCC vs CC activities is available, it still may be interesting to compare its merit in terms of cost or effectiveness with the alternative of compensating land users for the foregone development benefits.

that land users in the relevant tract will have to be compensated for the foregone conversion benefits. The case of no activity allowed at all in the conservation area is a special case of the one considered here. In particular, compensation should be paid gross of the benefits from activity 2 if this is regarded as not compatible with conservation; net, if activity 2 is allowed.

In the latter case, compensation T is given by:

$$T = \int_0^{x^*} \left(r_1(x) - r_2(x) \right) dx = \frac{\left(a_1 - a_2 \right)^2}{2\left(t_1 - t_2 \right)} \quad \textbf{(10)}$$

When only activity 2 is allowed, by redistributing amount T among land users residing in the tract $[0, x^*]$ it should be possible to make everybody as well off as in the no-intervention case.

One problem[11] with this solution is enforcement, which is not costless, as implicitly assumed above, and thus not necessarily complete. Land users entitled to compensation may have an incentive to carry out activity 1 in the tract $[0, x^*]$ *and* collect their share of T, the total overall compensation. The organisations involved in the scheme will therefore have to provide the resources necessary to enforce it.

---

[11] An additional issue, not addressed here, one concerns information: how many land users reside in the tract $[0, x^*]$? What is the exact pattern of the r_1-r_2 function therein?

The simplest way to capture some aspects of the problem is to imagine land users facing an expected utility maximisation problem, where a choice has to be made between two options (cheat, no cheat), and where there are two only two states of the world (detect, no detect). If land users 'cheat', that is, collect payment but do not respect zoning, they may be detected with probability ***p***; it is assumed that detection always implies conviction, and that no wrongful detection is possible. If land users are detected, they face a penalty, the monetary equivalent of which is the fine ***f***. Land users are compensated in the amount ***c*** for the opportunity cost of conservation at their location ***x***: $c(x) = r_1(x) - r_2(x)$. The fine is for simplicity assumed to be a multiple of ***c***: $f(x) = \mu c(x)$. That is, detected cheaters will have to return compensation received, plus, if $\mu>1$, a fine proportional to it. Actions, events, probability, pay-offs and utility are summarised in Table 2-2. Utility will be assumed equal to pay-offs only under risk neutrality.

Table 2-2 Compensation for foregone uses of land: matrix of payoffs

Action	Event	Probability	Pay-off	Utility
Cheat, ***ch***	detected	p	$r_1(x) - c(x)(\mu-1)$	$u(r_1(x) - c(x)(\mu-1))$
	not detected	1 - p	$r_1(x) + c(x)$	$u(r_1(x) + c(x))$
Do not cheat, ***nch***	not detected	1	$r_2(x) + c(x) = r_1(x)$	$u(r_1(x))$

The expected values are: $E(ch) = r_1(x) + c(x)(1 - \mu p)$; $E(nch) = r_1(x)$. So, assuming risk neutrality, at any distance land users will not cheat if $E(nch) \geq E(ch)$, which implies:

$$\mu p \geq 1 \qquad \textbf{(11)}$$

This has the obvious interpretation that the expected value of the penalty must be larger than compensation, at any location x.

What is the cost of enforcing land use restrictions? The probability of detection p is assumed to be an increasing, concave function of l, labour employed to patrol; the function is bounded from above as p can note exceed unity: $p = p(l);\ p' > 0;\ p'' < 0;\ p(\infty) = 1$. For a given μ, labour required to enforce zoning,l , solves: $p(\hat{l}) = \frac{1}{\mu}$. However enforcement will be more difficult, and hence more costly, as distance from the central business location increases. Denoting with τ the cost per unit of distance of transporting a unit of labour, the enforcement cost per 'enforcing unit of labour'(l), $e(x)$ at location x is: $e(x) = 1 + \tau x$, where the wage rate has been normalised to unity. Total enforcement cost is then:

$$E(\hat{l}) = \int_0^{x^*} e(x)dx = \left[x^* \left(1 + \frac{\tau^2}{2} x^* \right) \right] \quad \textbf{(12)}$$

The total cost of the scheme, S, is thus given by the sum of compensation and monitoring cost: S=T+E(l).

The cost of the scheme will clearly be sensitive to risk attitudes. For instance, in the case of risk aversion, the enforcement condition becomes:

$$r_l(x) \geq r_l(x) + c(x)(1 - \mu p) - h \qquad \textbf{(13)}$$

with h denoting the certainty equivalent of the 'cheating gamble'. This gives $\mu p \geq 1 - \frac{h}{c(x)}$, which implies that at any level of penalty rate μ, the required probability of detection, labour input, and enforcement cost is less than in the risk-neutrality case (see Figure 2-5). The reverse will be true in the risk-loving case.

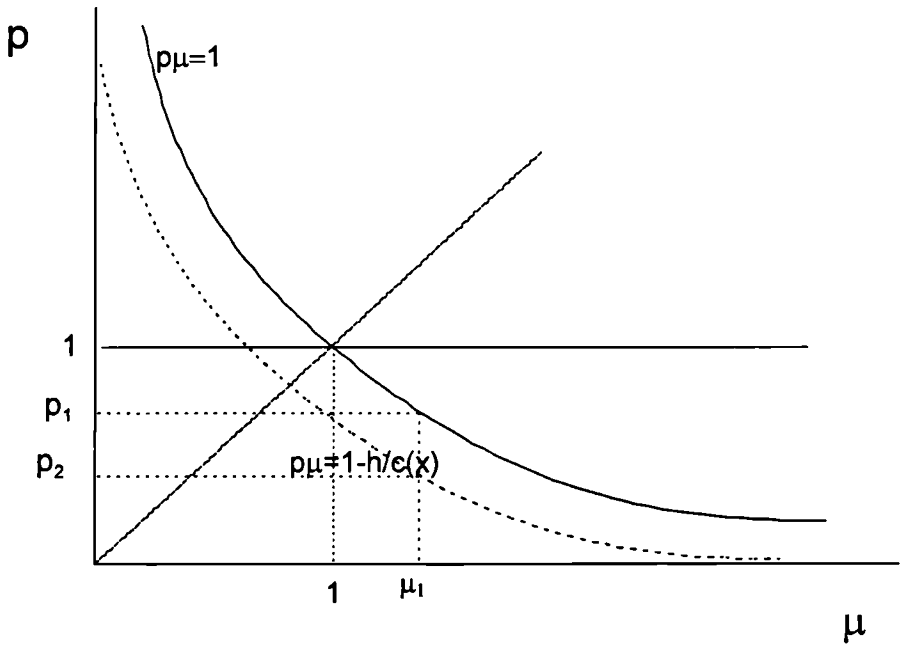

Figure 2-5 Enforcing land use restrictions: the relation between penalty and probability of detection

2.3.2.1. Tradeable development rights and franchise agreements

The previous section has sketched a very simple framework which could be used to analyse schemes of restrictions on land use. To carry the analysis forward, it is necessary to consider how could such a scheme actually work. One possible form compensation could take is purchase of development rights. This option has been recently the object of some attention in the literature (Katzman and Cale, 1990), (Panayotou, 1994). The idea is essentially that landowners could be asked to give up their rights on some uses of land (e.g. burning the forest, or developing land beyond a given level of intensity) in exchange for a money payment. The state could also be involved in the management of the scheme, as in the case of the suggested International Franchise Agreements (IFAs) (Swanson, 1993).

An IFA is a concession, by the state, of exclusive rights on land to a franchisee, with limitation on allowable uses in the interest of a third party. As explained by Swanson (1992),

> "in the case of the Brazilian Amazon, the franchise would be a limited term of use of a specified property within that region subject to specific restrictions. The grantor would be the owner-state (O-S), e.g. Brazil. The franchisee would be the entity allocated the franchise. The third party is the global community, represented by bilateral agreement between an international organisation such as the World Bank, and Brazil. The IFA operates by the O-S dividing the total development rights for the particular parcel of land between the

GC and the Franchisee in a way that maximises the O-S's return from that land. The O-S then collects a rental payment from the franchisee for its use of the franchise, and a rental payment from GC for the restrictions placed upon that franchise. Both "holders" of development rights (franchisee and GC) have an incentive to police their own allocations; the owner-state has the incentive to respond to intrusions on its holders' rights in order to maximise the value of its auctioned rights in the future (and to receive the future rental streams from both rights allocations). This mechanism allows the expression of GC's preferences within O-S in an incentive compatible fashion, which is the solution to the underlying problem". The structure of an IFA is represented in Figure 2-6.

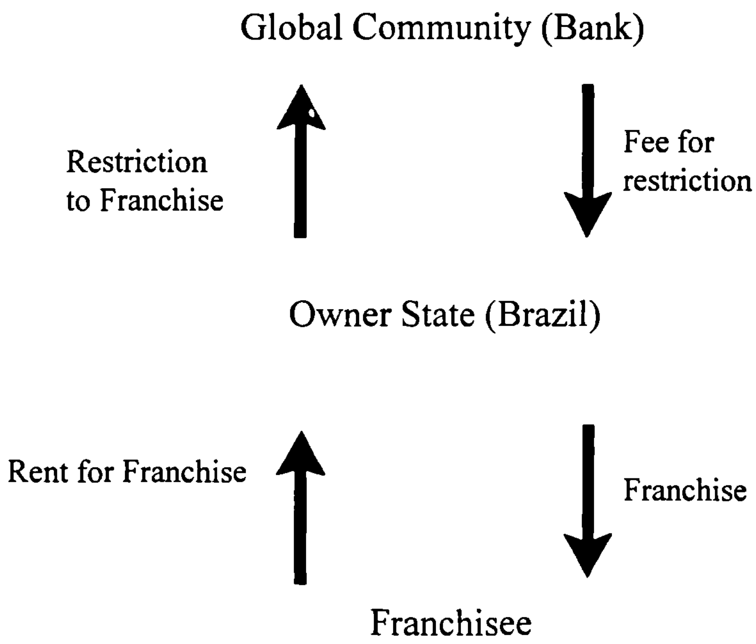

Figure 2-6: The Structure of an IFA

According to the International Franchise Agreement (IFA) approach, the owner state confers exclusive rights on land to a franchisee in exchange for a payment, and it imposes restrictions on admitted uses in exchange for a compensation fee paid by a third party (the international community).

The mix of charges for admitted uses and compensations for prohibited uses would affect the individual perception of returns from alternative activities. The decision on whether to engage in an admitted activity or in an illegal one will depend on the policing effort of the body responsible for the enforcement for the restriction. It will also depend on the share of compensation fee the owner state will decide to transfer to local resource users.

Tradable development rights and IFAs seem a promising option for future conservation policies. One indispensable condition for the implementation of these schemes is the existence of clearly defined (and enforced) property rights on land. Such a condition does not yet fully hold in several developing countries, which, like Mexico (the subject of the case study of chapters 4 to 6) are still in the process of modifying land tenure legislation and/or implement land titles regularization programs.

2.4. *Conclusion of chapter 2: analysing land use change in theory and in practice*

Based on the strong empirical evidence of land use changes throughout the world, this chapter has summarized the theoretical link between land use changes and biodiversity loss, proposed a diagrammatic interpretation of a typical sequence of land conversion prevailing in developing countries, and discussed options for tilting the balance of incentives in favor of activities compatible with conservation of biodiversity.

The analysis of this chapter, primarily theoretical, will be complemented by the empirical part of the dissertation (chapters 4 to 6). Using primary field data from Mexico, both the analysis of land use change processes, and the discussion of strategies to conserve biodiversity will be reformulated and adapted to local circumstances, in an attempt to add realism to the ideas discussed in this chapter.

Regarding the analysis of the process of change, a first issue has to do with the spectrum of land uses considered. Casting the problem in terms of binary choice between conservation and development is an oversimplification. In reality, there is a continuum of intensity of human uses, ranging from high intensity uses, such as urban development, to low or no-intensity, such as primary forests. Each use will have different impacts on biodiversity, as it will create the conditions for the survival of some plant and animal communities, and for the decline, and eventually extinction, of others[12].

Because of this variety of impacts, the choice of the optimal mix of land uses will be dictated by the particular biodiversity conservation objective selected by policy makers. Even if there seems to be no clear consensus among ecologists about the "right" objective function, and thus about the optimal land use mix, it is nevertheless important to analyze social and economic processes that determine the allocation of total land available to all the uses included in the spectrum of human activities, not just the uses at its two extremes. The results of such an exercise could be used as input for policy making.

On the basis of an analysis of farm-level resource allocation decisions, the empirical part of the dissertation will propose a model for predicting changes in selected land use types of the study area, including primary forest, second growth vegetation, farm land and pasture.

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[12] An interesting observation made by recent scientific literature, is that low and moderate intenisty regimes of land uses, such as extraction from secondary forests, or agrforestry systems, have an important role in biodiversity conservation, perhaps not substitute, but at least complementary, to the role of pristine ecosystems (Brown & Lugo, 1990; Gomez Pompa, Whitmore, and Hadley, 1991; Smith, 1996; Nepstad, Uhl et al., 1991; Estrada. A., Coates - Estrada et al., 1993). Some authors have even highlighted the role of selected agricultural systems as reservoirs of diversity of particular associations of plants and animals (Srivastava, Smith, and Forno, 1996; Paoletti, Pimentel et al., 1992; Paoletti & Pimentel, 1992; Pimentel, Stachow et al., 1992)

A second element concerns land tenure. The peasant pioneer sequence discussed in this chapter assumes the absence of property rights on land. In reality, several countries in Latin America and elsewhere are considering or implementing land reforms aimed at improving tenure security. Establishment of property rights is likely to decrease one source of incentives for conversion.

However, it may also be important to address the situation that occurs in the transition from open access to the new tenure system, especially when household without secure tenure face the risk of eviction, and don't have many employment opportunities outside the rural sector. Chapters 4, 5 and 6 will discuss the possible implications in terms of pressure on natural resources, of the title regularization program currently being implemented in Mexico.

Concerning the alteration of incentives for conservation and development, the Mexico case study will look not only at ways for improving the attractiveness of activities compatible with conservation, but also at technological options for reducing the land intensity of activities, such as ranching or agriculture, that have detrimental impacts on diversity.

Chapter 3

Financing conservation: theoretical aspects

3.1. INTRODUCTION.

Conservation of biological resources generates local, national and international benefits[1]. Country-level activities, which result in depletion of biodiversity, generate transboundary externalities affecting the rest of the world. This chapter addresses the issue of how those externalities can be internalized through the "incremental cost" mechanism; it does not deal with the problem of how the international community could reach agreement (or fail to do so) on sharing of the cost of conservation. This topic has been analyzed elsewhere in the literature (see for example Barrett, 1994).

The existence of transboundary externalities associated to biodiversity conservation justifies the need for co-ordinated action at the international level. The Convention on Biological Diversity (CBD) is the most important attempt to date to promote such collective action. The Convention stipulates that all the signatories have an obligation to undertake a number of actions to conserve biological resources. It also requests developed countries to provide developing countries with the resources necessary for them to comply with the convention. An institutional structure is established to manage the resulting financial transfers from the former group of countries to the latter. The

[1]For some overviews on the economic values of biological resources, see Cervigni (1993), Pearce (1993), Pearce and Moran (1994).

institution that operates on an interim basis the financial mechanism of the Convention is the Global Environment Facility (GEF).

The specific criterion regulating the financial mechanism of the convention is the "incremental cost" principle, which is also adopted by two other major environmental conventions, the Montreal Protocol on Ozone Depleting Substances, and the Framework Convention on Climate Change. Article 20 of the CBD dictates that developed countries will provide resources to enable developing countries to meet the "full agreed incremental cost" to them of undertaking the conservation measures required by the convention.

During its "pilot phase" (1991-1994), the Global Environment Facility has been funding projects for about US$ 730m, with biodiversity conservation projects amounting to 45% of the total[2]. Funds have been disbursed on the basis of "full", rather than "incremental" costing. In recent times, policy negotiations and applied research[3] have been undertaken to foster the complete application of the financial provisions of article 20. These have been prompted by the move from "pilot" to "operational" phase of the GEF, which has been restructured and replenished for US $ 2 billion in early 1994, and by progresses towards the full implementation of the Convention. The debate has revolved around the

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[2]Funds in the other GEF focal areas have been divided as follows: Climate Change 36%, International Waters 16%, Ozone depleting substances phaseout 1%, Multiple Areas 2%. (Source: Global Environment Facility, 1994 and other years).

[3] An example of the latter is the Program for measuring Incremental Cost for the Environment (PRINCE), core-funded and managed by the GEF. Started in 1993, PRINCE is a program of technical studies aimed at testing methodologies, undertaking case studies and disseminating results in the area of incremental cost (King, 1993c). In the biodiversity area, case studies have been carried out in Mexico (Cervigni and Ramirez, 1996), Indonesia, Malaysia and Vanuatu (Giesen and King, 1997).

exact meaning and scope of the notion of incremental cost, and its applicability to the biodiversity context.

The Convention provides little guidance for the discussions, as none of the terms used in introducing incremental cost is further defined. Despite this indeterminacy, there is some consensus[4] that in broad terms incremental cost encompasses all the costs of actions that countries undertake because of the Convention, and that they would otherwise not undertake. Incremental cost is thus defined by contrast with a (hypothetical) baseline representing the situation without the Convention.

To make this simple definition more operational, some further element has to be added. First, conservation actions might generate benefits as well as costs to the countries undertaking them. Should these additional benefits be netted out of incremental cost? The phrase "agreed full" could refer to the percentage of domestic benefits to be deducted from the transfer of resources meeting incremental cost.

Second, there is the issue of the baseline. When the existing price system is distorted in such a way to encourage depletion of biological diversity, should the baseline be evaluated net or gross of distortions?

In both cases, there is a trade-off between likelihood of effective conservation and cost efficiency.

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[4]See, for example, Pearce and Barrett (1993), King (1994), Pearce, Cervigni and Moran (1994).

If domestic incremental benefits are not deducted from the amount of resources transferred from developed to developing countries, countries hosting biological resources will end up better off with the transfer than without it, and will have more incentive to comply with the convention. On the other hand, the cost per unit of additional conservation will be higher, and, for a given size of the budget available, less biological resources will be conserved.

Similarly, a distorted baseline is more likely to be acceptable to the host country. This will be so if, by using undistorted shadow prices in calculating incremental cost, compensated resource users end up worse off than in the baseline. At the same time, a distorted baseline is likely to result in higher unit cost of conservation, and again, less biodiversity conserved overall.

To address these issues in a more systematic fashion, a simple partial equilibrium, demand-side model is proposed here, with only two agents: a representative country hosting biological diversity, and a homogenous international community, interested in higher levels of conservation than those prevailing in the status quo.

Section 3.2 introduces the basic model and defines three situations: the domestic optimum, which prevails before the Convention; a hypothetical Global Optimum, and finally the situation prevailing after the ratification of the convention.

To fully characterise the latter situation, section 3.2.4 introduces two further ways in which the financial mechanism of the Convention could possibly work. The distinction depends upon the way the host country may act in the implementation process. The host may either commit itself to a given level of conservation and try to get the highest level of compensation corresponding to that level (quantity-taking behaviour). Or it may take the amount of resource transferred as given, and then choose the utility-maximising level of conservation (transfer-taking behaviour). The main idea is that the equilibrium level of conservation is endogenous to the trading process between the host country and Rest of the World, and will not necessarily coincide with the global optimum.

Section 3.2.5 introduces domestic price distortions into the analysis. Section 3.3 proposes simple functional forms for the utility of the host country and of the international community: this makes it possible to draw some specific conclusions on the comparative merits of the domestic optimum and the incremental cost scheme, both in the absence and in presence of domestic price distortions.

Section 3.4 provides some tentative conclusions.

3.2. BIODIVERSITY CONSERVATION AND INCREMENTAL COST: A SIMPLE MODEL

There are two countries: one host country, H, which conserves an environmental commodity (biological resources), generating global benefits, and the rest of the World, ROW. Utility in both the host country and the rest of the world depends upon consumption of a single non-environmental good (x for H and X for ROW) and upon conservation of biological resources, q. We can think of q as some suitable measure[5] of natural systems' health (e.g. percentage of land maintained in relatively undisturbed conditions), which can be used a proxy for conservation of biodiversity. The literature normally highlights that benefits of biodiversity can be classified according to the spacial level where they accrue (national and international), and according to their nature (social or private).

Table 3-1: Assumptions about benefits generated by biodiversity

Type of benefits	Level at which benefit accrue	
	National	International
Private	Yes	No
Social	No (see text)	Yes

[5]Of course the issue of what such a measure should be is in itself the subject of a voluminous literature. See the various chapter of Heywood (1995).

As indicated by Table 3-1, the choice has been made to include only some of those benefits in the present analysis. In particular, this model concentrates on allocative distortions related to the international externalities of conservation: the level of q is selected by the host country but affects ROW's utility (for example, via existence values), and so is an externality for the latter. From the point of view of the host country, it is assumed that q mainly generates privately approriable benefits. For example, if q is the percentage of land under forest cover, any given level of q will be associated with some level of sustainable timber harvesting, or extraction of non-timber forest products. To the extent that this type of benefits are easily monetized and readily transformed into income and wealth, this approach is consistent with the preamble of the Convention on Biological Diversity. This stresses that "economic and social development and poverty eradication are the first and overriding priorities of developing countries", so that, by implication, uses of biodiversity more directly related to those priorities have preeminence in determining the position of developing countries in conservation-related negotiations.

There are of course also important domestic social values stemming from biodiversity conservation, like for example watershed protection or micro-climate stabilisation[6]. Often domestic externalities from conservation are especially important at the local or subnational level, but are not perceived at the national level in a way strong enough to shape the country's negotiating position. This may be so for political economy factors. Consider for example, logging concessions to be granted in a fragile watershed. Local communities, who will be affected most by the possibly resulting disruption of the watershed, may be not as effective in defending their interest with the government as the lobby of the logging concessionaires.

For the time being, domestic social benefits will be assumed irrelevant in determining the host's negotiation position. Section 4 will modify this assumption, in that it will take into account more general distortions in the pricing system of the host country.

In summary, this model studies the way in which the host and ROW negotiate about the provision of international benefits from conservation. To characterise the problem, we identify three situations. In the first one, which exemplifies the situation prior to the Convention on Biological Diversity, both parties operate in isolation. The host country decides on the optimal combination of x and q on the basis of its own preferences and income only. The Rest of the World takes the level of q selected by the host as given, and is constrained to spend all of its income on good X.

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[6] It is plausible to assume that in most developing countries use values (both direct and indirect) will be the most relevant in determining preferences for biodiversity conservation. Non-use value, such as existence value, are likely to be relevant in countries with higher per capita income.

The second situation represents the hypothetical global optimum, in which a benevolent world dictator determines the optimal provision of the man-made goods, x and X, and of the environmental commodity q, taking into account both parties' preferences.

Finally the third situation is the one arising out of the Convention on Biological Diversity, which establishes a financial mechanism to encourage conservation in countries hosting biological resources.

The model can be intended as analysing resource allocations over a number of possible conservation projects large enough to justify the use of continuous variables. These projects are to be co-funded by a single representative host country and the Rest of the World. The analysis is static, and purports to identify equilibrioum allocation outcomes and welfare implications for host and ROW in the various situations considered. The results obtained here can be used as inputs for future work attempting to deal with the topic at hand through dynamic analysis tool, so as to take into account issues of commitment and credibility which are not addressed here.

The notation used in what follows is summarised for convenience in Table 3-2.

Table 3-2: notation used

H:	Host Country
ROW:	Rest of the World
q:	quantity of environmental commodity with global benefits
p_q:	price of environmental commodity
x:	quantity of non-environmental good consumed by Host
p_x:	price of good x
X:	quantity of market good consumed by Rest of the World
p:	vector of prices in host country (p_x, p_q)
b:	income of host country
B:	income of rest of the world
u(.):	Host country utility function
U(.):	Rest of the World utility function
u_i, u_{ij}:	First, second derivatives of function u with respect to variable i, and variable i and j
U_i, U_{ij}:	First, second derivatives of function U with respect to variable i, and variable i and j
e(.):	expenditure function of host country
γ:	"clawback" factor indicating the share of domestic benefits deduction from incremental cost
δ:	price-distortion factor
σ:	factor indicating a subsidy rate paid by ROW
$\phi(q)$:	"parametric" utility function for the Host. It answers the question: for given prices, what level of utility can be reached when q is chosen optimally?
$variable_d$:	Indicates level of the given variable determined as a result of domestic optimization in host country
$variable_g$:	Indicates level of the given variable determined as a result of global optimization
$variable_\gamma$:	Indicates level of the given variable determined as a result of incremental cost compensation; when $\gamma=\gamma 0$, under transfer taking behaviour; when $\gamma=\gamma^*$, under quantity taking behaviour;

3.2.1. Before the Convention

In accordance with the assumptions spelled out above on the domestic benefits of q, we will assume that the privately appropriable benefits of conservation are reflected in a market price p_q (this can be thought of as a composite price index of conservation-compatible goods, e.g. sustainably harvested timber, non timber forest products, etc.). The possibility that such a price does not reflect the social value of q will be addressed in section 3.2.5.

The problem of the Host country is then:

$$\operatorname*{Max}_{q,x} u(q,x) \quad s.t. \quad p_x x + p_q q = b \qquad 1$$

The Host country's equilibrium is assumed to exist and is represented by the pair (x_d, q_d), with the associated utility level u_d.

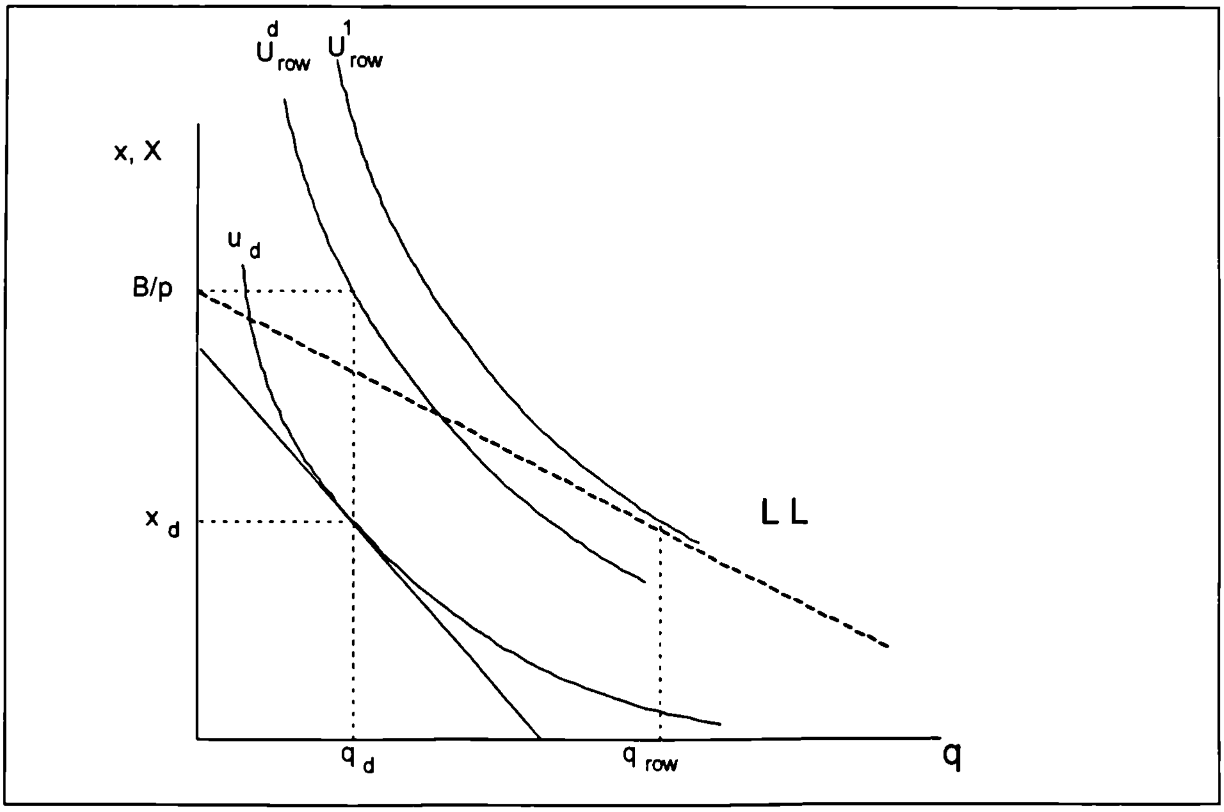

Figure 3-1 **ROW's constrained and unconstrained optima**

The problem of the Rest of the world is:

$$\operatorname*{Max}_{X} U(q_d, X) \quad s.t. \quad p_x X = B \qquad 2$$

The rest of the world is quantity constrained by the host's choice of qd, and is thus forced to spend of all its income on good X. The resulting equilibrium is therefore given by the pair (X_d=B/p_x, q_d). Figure 3-1 illustrates the host's equilibrium and the Rest of the World constrained equilibrium. ROW faces an horizontal budget constraint; if there was the possibility of introducing a downward sloping budget constraint (i.e. if ROW were enabled to spend some of its income on q), ROW might achieve higher utility. For example, in Figure 3-1, the hypothetical linear budget constraint LL induces ROW to optimize at $q_{row}>q_d$, and enables it to reach a higher indifference curve, $U^1_{row} > U^1_d$. The interpretation suggested here to the Convention on Biological Diversity (see below for details) is thus that it introduces a way of relaxing ROW's quantity constraint, and of making its budget constraint downward sloping[7].

[7]In the interpretation of the present model, the Convention on Biological Diversity introduces a particular, quantity-based, mechanism for the international financing of biodiversity conservation. In principle, one could also consider some other, price-based, instrument to induce the host to push conservation beyond q_d. One possibility is a fixed subsidy rate σ (with $0<\sigma<1$) for any unit of conservation in excess of the domestic optimum q_d. A previous, longer version of this paper (Cervigni, 1995) provides a more detailed analysis of the issue, with a number of quantitative results obtained by considering specific functional forms.

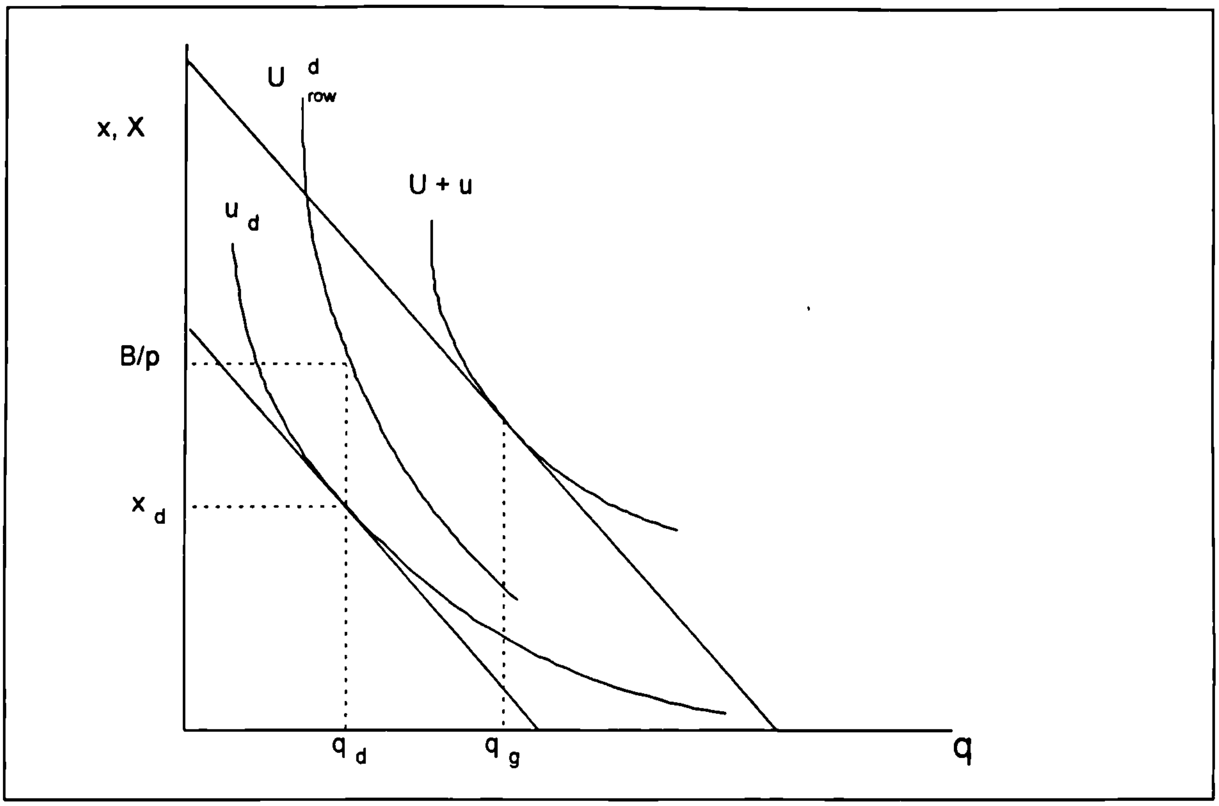

Figure 3-2Domestic and Global Optima

3.2.2. The global optimum

In this situation, it is assumed that both host's and ROW's welfare are taken into account in determining the equilibrium combination of x, X and q. For simplicity, let us assume a Benthamite utilitarian global welfare function, whereby utilities are given equal weights and summed. The problem is given by:

$$\max_{q,x,X} u(x,q) + U(X,q) \quad s.t. \quad p_x(x+X) + p_q q = b + B \tag{3}$$

First order conditions for a global optimum are:

$$\frac{u_q}{u_x}+\frac{U_q}{U_X} = \frac{p_q}{p_x}; \qquad U_X = u_x; \qquad B+b = p_x(X+x)+p_q q \qquad 4$$

The first condition has the interpretation that the sum of the marginal rates of substitution must be equal to the price ratio. This is the familiar [Samuelson, 1954] rule for the optimal provision of public goods. The Global optimum, which satisfies the above condition is the vector: (x_g, X_g, q_g). The corresponding utility levels are given by u_g and U_g. The global optimum is displayed in Figure 3-2: host's and ROW's indifference curves sum vertically to generate the global indifference curves U+u. The global optimum is identified by the point of tangency of the function U+u with the aggregated budget constraint.

3.2.3. After the Convention

The Convention on Biological Diversity stipulates a number of measures[8] contracting parties should undertake to conserve biological resources. Furthermore, it establishes that developed countries are to provide "new and additional" financial resources to meet the "full agreed incremental cost" incurred by developing countries in complying with the convention (i.e. undertaking the indicated conservation measures, thereby providing a

[8]These are specified, with various degree of detail, in articles 6 through 19, and fall below the headings of: General Measures, Identification and Monitoring, In-Situ Conservation, Ex-Situ Conservation, Sustainable use of Components of biological diversity, Incentive Measures, Research and Training, Public Education and Awareness, Impact Assessment and Minimizing Adverse Impacts, Access to Genetic Resources, Access to

level of conservation q higher than q_d). This provision of the convention effectively introduces the possibility of a "trade" in conservation between developed and developing countries: the latter will agree to conserve more than they would otherwise do, and, in exchange, the former meet the corresponding incremental cost. Unfortunately, the terms of the transaction are far from being precise, since, in introducing the concept of incremental cost, the Convention fails to define:

a) incremental to what (i.e. what is the baseline);

b) what does "agreed full" mean;

c) cost of getting where: that is, how much further than q_d should the host's conservation effort be pushed?

As summarized in Pearce and Cervigni (1994), and discussed in Glowka *et al.* (1994), a variety of differing interpretations has been proposed in recent times on these issues, which are still the subject of political and legal controversies. For the present purposes, we will assume:

a) The baseline situation is the domestic optimum (xd, qd). Until section 3.2.5, it will be assumed that there are no price distortions affecting the determination of the domestic optimum.

b) In general, actions to conserve biological resources will generate benefits as well as costs. We will thus assume that "agreed full" means there will be an agreement between

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and Transfer to Technology, Exchange of Information, Technical and Scientific Cooperation, Handling of Biotechnology.

Host and Rest of the World as to what percentage of incremental domestic benefits has to be deducted from the incremental cost. In the context of the present model, "cost" is the expenditure necessary for purchasing a particular combination of goods q and x; "benefit" is the level of utility associated with the selected basket of goods. If the host were to select a level of conservation higher than q_d, it would incur a cost (i.e., spending more than b), but it would also gain a benefit (reaching a utility level higher than ud).

The notion of "agreed full incremental cost" can then be translated in the following way: for any level of conservation q in excess of the domestic optimum, ROW will have to provide a transfer T(q) equal to the gross incremental cost minus an "agreed" fraction g, varying between 0 and 1, of any incremental benefit:

$$T(q) = e(p, \phi(q)) - e(p, u_d) - \gamma\left(e(p, \phi(q)) - \tilde{e}(p, u_d, q)\right)$$

Equation 5

The symbols have the following meaning: e(.) is the expenditure function for the host country; normally, the arguments of the expenditure function are prices and utility. Instead of being a parameter, utility ϕ is here expressed as a function of ***q***. The function $\phi(q)$ indicates, for given prices, the level of utility that would be reached when the Host optimally chooses conservation level ***q*** (and when it is endowed with the necessary income, which is precisely e(p, ϕ(q)). The function $\tilde{e}(\cdot)$ is the constrained expenditure function, i.e. is the solution to the problem:

$$\underset{x}{\text{Min}}\; p_x x + p_q q \quad s.t.\;\; u \geq u_d, \quad q\text{: parameter}$$

Equation 6

Its argument are prices p, the "reference" level of the domestic utility ud, and conservation q. The function $\tilde{e}(\cdot)$ indicates the minimum expenditure necessary to keep the host's utility constant at u_d when conservation level q is chosen[9].

No transfer is forthcoming if conservation does not increase: $T(q_d)=0$. The graphical interpretation of the T(q) function is provided in Figure 3-3.

[9]It may be argued that the loss of utility associated to any sub-optimal choice of q (i.e. to any non-zero level of γ), is itself a cost to the host country, hence eligible for incremental cost compensation. This argument is valid only if the principle is accepted, that incremental cost should always be paid gross of incremental domestic benefits. But as mentioned before, there is no explicit indication in the Convention of Biological Diversity that this should be the case. Indeed, one of the purposes of the model is to suggest a possible way out of the indeterminacies of the Convention.

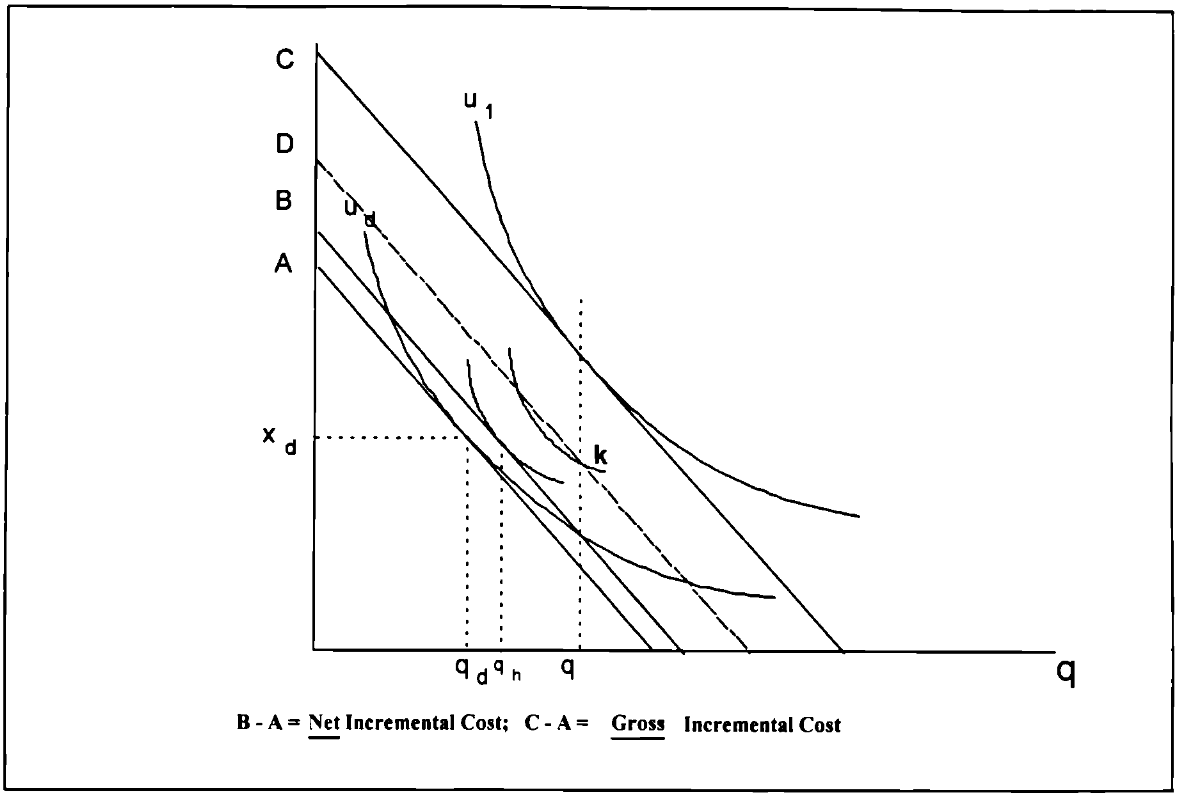

Figure 3-3 Gross and net incremental cost

The host's initial income (evaluated in terms of good x) is A. For the host to be willing to reach the generic conservation level $q>q_d$ it must be given at least income B-A, which will leave it on the original indifference curve (corresponding to the domestic optimum, u_d). Keeping q constant, any income in excess of B will make the host better off; income C is defined as the income level at which the host would freely choose conservation level q. So, the difference C-A is interpreted here as the gross incremental cost of moving from q_d to q.

The term γ is a "claw-back" factor indicating what percentage of domestic incremental benefits are deducted from the transfer. When $\gamma=0$, no incremental benefit is deducted, and the transfer is equal to the gross incremental cost; in, Figure 3-3, the transfer is equal to C-A. When $\gamma=1$, all of the incremental benefits are deducted, and the transfer is equal to the net incremental cost, which, in Figure 3-3 is equal to B-A. Notice that for any $q>q_d$ by definition of the function $\phi(q)$ the host optimizes only for $\gamma=0$; however, suboptimal choices of $\gamma>0$ can still make the host better off, relative to the domestic optimum. For example, in Figure 3-3 a transfer of D-A, which corresponds to some value of g intermediate between 0 and 1, leads the host to the suboptimal, but welfare-improving, point k (it lies on an indifference curve higher than u_d).

3.2.4. "Quantity-" And "Transfer-Taking" Behaviour

Point c), concerning the level of conservation induced by the convention, deserves some discussion. One interpretation of the convention is that its purpose is to achieve the global optimum[10]. The relevant incremental cost is then the cost of moving from q_d to q_g, whatever this cost may be. Under this interpretation, host and Rest of the World would bargain only about the way domestic incremental benefits should be considered, that is, they bargain about the level of γ.

[10]The Convention on Biological Diversity does not use the expression "global benefits". However, the preamble to the Convention affirms that "the conservation of biological diversity is a *common concern* of mankind", and stresses the "intrinsic" value of biodiversity, and its importance "for the evolution and for maintaining life sustaining system of the biosphere. That is, stresses the "public good" components of the value of biological diversity. Critics of this view point out that the preamble does not impose binding commitments upon signatories in the same way the actual text of the convention does.

However, the Rest of the World will want to go for the global optimum only if this is compatible with its budget constraint; similarly, the host might not want it either, if this makes it worse off than the domestic optimum.

Therefore, the present model proposes a description of the negotiation process between Host and Rest of the World, rather than assuming that the automatic outcome of the Convention on Biodiversity is the achievement of the global optimum q_g. For simplicity, we will assume that negotiation can work in two ways: the host may either commit itself to a particular level of conservation q in excess of q_d and then negotiate the compensation accordingly (ROW chooses q and Host claims T(q); or it may take compensation as given and select conservation accordingly (ROW offers T and Hosts chooses q(T)). In the first case, the Host can be defined as a "quantity taker"; in the second, a "transfer taker". In order to concentrate on equilibrium outcomes, we will assume that the cost to ROW of monitoring the actual enforcement of the host's commitments are negligible, and that, as a result, the host has little incentive to deviate from its conservation pledges. Issues of credibility and possible reneging of promises are of course important in the present context, and the assumption of perfect information might be relaxed in a more complex model. However, the main objective of the present analysis is to illustrate the allocative implications of the incremental cost mechanism, not the difficulties associated with its implementation.

We will first examine the case where the Host is quantity taker, and see what level of γ and of conservation q will prevail in equilibrium.

If the Host is a quantity taker, it will commit itself to whatever level of conservation ROW will decide to finance, but it will then try to get as much incremental domestic benefits as possible (i.e. a value of γ as low as possible). Even if it would seem that for the host the best policy would always be to have all of the incremental benefits (i.e. $\gamma=0$), this will not in fact be necessarily the case, as we will see below, as the conservation level (and hence the availability of incremental benefits) is dependent on the value of γ agreed upon.

The problem for ROW becomes:

$$\underset{X,q}{\mathrm{Max}}\, U(X,q) \quad s.t. \quad p_x X + T(q) = B \tag{7}$$

Note that according to Equation 5, T(q) is a function of the unconstrained and constrained expenditure function, e(q) and $\tilde{e}(q)$. These in turn, involve the optimizing behaviour of the host, so that, in fact, ROW faces its own budget constraint, *plus* the constraint implicitly defined by T(q).

Optimality requires:

$$\frac{U_q}{U_x} = \frac{1}{p_x}\left\{(1-\gamma)(p_q + p_x\alpha) + \gamma(p_q - p_x\beta)\right\};$$

$$\alpha = \frac{u_q u_{qx} - u_x u_{qq}}{u_x u_{qx} - u_q u_{xx}}; \qquad \beta = \left.\frac{u_q}{u_x}\right|_{u=u_d}$$

Equation 8

(The derivation of the quantities α and β is reported in Annex 3-1). Assuming an interior solution, this is represented by the pair (X_γ, q_γ), which depend on the value of γ. Diagrammatically, as γ changes, so does the budget constraint faced by ROW in its optimization problem; Figure 4 illustrates a case in which, when γ decreases, the budget constraint moves downwards, and the equilibrium level of conservation decreases. If, in particular, γ=1, i.e. the resource transfer is equal to the incremental cost <u>net</u> of incremental domestic benefits, the condition contained in Equation 8 becomes:

$$\frac{U_q}{U_X} + \left.\frac{u_q}{u_x}\right|_{u=u_d} = \frac{p_q}{p_x} \qquad 9$$

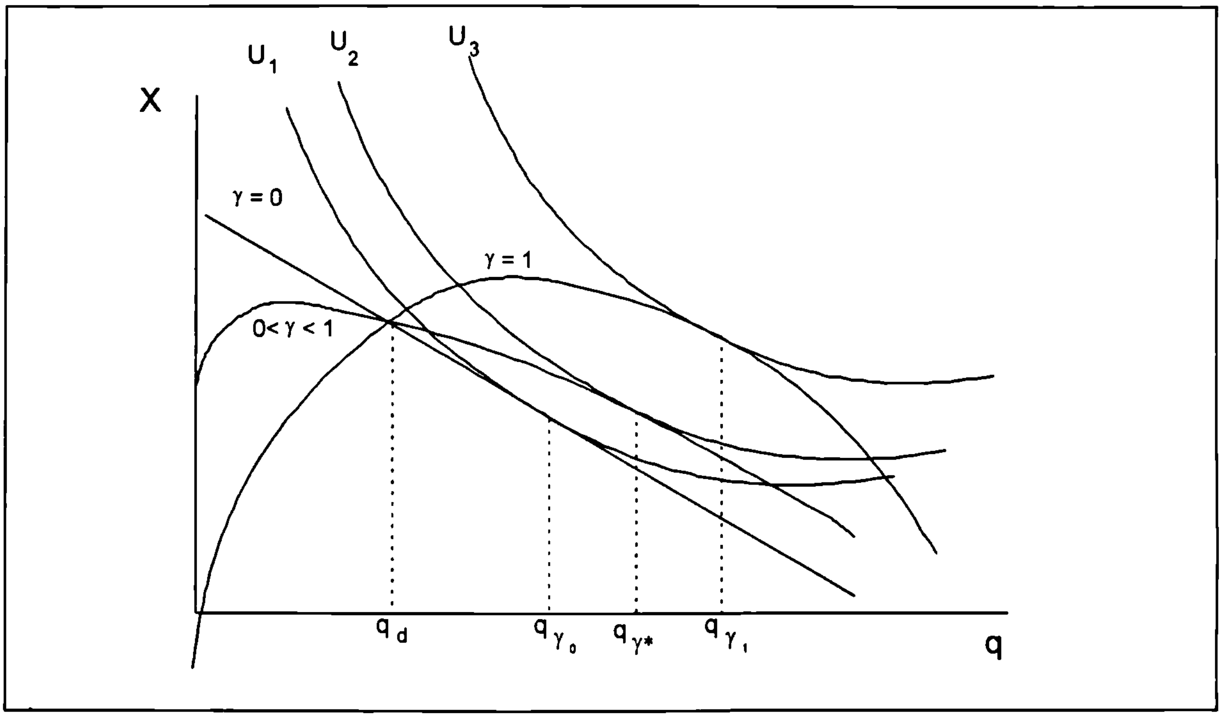

Figure 3-4 Equilibrium for Rest Of the World

Figure 3-4: The diagram depicts ROW's indifference curves and budget line in the q-X space. As the clawback factor γ changes, so does the budget constraint faced by ROW in its optimisation problem. In the particular case depicted in the diagram, where ROW's utility is multiplicative (U=qX), when γ decreases, the budget constraint moves downwards, and the equilibrium level of conservation decreases. The value $q_{\gamma 0}$ *defines the transfer-taking solution; the quantity-taking solution* $q_{\gamma *}$ *will be somewhere in between* $q_{\gamma 0}$ *and* $q_{\gamma 1}$.

Comparing this to condition *4*, it turns out that when incremental cost is paid net, the equilibrium level of conservation coincides with the global optimum. However, the equilibrium values of x and X will in general differ from the global optimum case. This is so because, as the utility of the host is kept constant, the equilibrium level of good x must be lower than in the global optimum case, otherwise the host would be better off than in the domestic optimum case.

This observation enables us to comment on the debate net vs. gross incremental cost[11]. The standard argument in favour of net incremental cost is its cost-effectiveness: more conservation can be achieved for any dollar spent when international resources are used to pay only the net cost of incremental conservation measures. In this model this argument is valid if we assume that the host country is a quantity taker, and it has no control over the "clawback" factor γ, or that it is willing to accept the value $\gamma=1$.Indeed, if the host has decided to follow a "quantity-taker" behaviour, it will be more likely to try and negotiate the clawback factor γ in such a way that it can maximize its own utility. From the point of view of the host, there are two forces at work, which interestingly push in opposite directions:

- on one hand, a smaller γ will take away less domestic benefits from the transfer, and thus make H better off;

- on the other hand, a smaller γ will induce ROW to choose a lower level of q_{row}, thereby reducing the size of the cake available to H, and making it worse off.

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[11]See, for instance, El-Serafy (1994), King (1994), Pearce, Cervigni and Moran (1994), Glowka *et al.* (1994)

In other words, as g decreases, H's slice of the "compensation cake" increases, but the size of the cake decreases. The host will then want to balance off, at the margin, size and slice effect. The quantity q_γ is defined by Equation 8; the equilibrium value of the non environmental good consumed in the host country, x_γ, can be derived by plugging qg in to the host's budget constraint:

$$p_x x + p_q q_\gamma = b + T(q_\gamma) = (1-\gamma)e(q_\gamma) + \gamma\tilde{e}(q_\gamma) \qquad \textbf{\textit{10}}$$

and solving for x (the second equality in the above expression results from re-arranging Equation 5, and noting that $e(p, u_d)=b$).

Substituting both q_γ and x_γ into the host's utility function, we obtain an indirect utility function, v, which depends on prices, income and the clawback factor γ:

$$v(p_q, p_x, b, B, \gamma) = u(x_\gamma, q_\gamma) \qquad \textbf{\textit{11}}$$

Assuming that the second order conditions are satisfied, the optimal value of the clawback factor can be obtained by equating the derivative of v with respect to γ to zero, and solving for γ. That is, finding the value of γ that solves:

$$\frac{u_q}{u_x} = -\frac{dx / d\gamma}{dq / d\gamma} \qquad \textbf{\textit{12}}$$

Conditions contained in Equation 8 and ***12*** jointly define the solution to the model in the quantity-taking case. The Host selects the optimal clawback factor, γ^*, taking ROW's optimisation as given; ROW, in turn, decides the optimal level of conservation q_{γ^*} once the Host has chosen γ^*.

Suppose now that the Host is a "transfer-taker". That is, for any particular value of the transfer, it will select the utility-maximizing values of q (and of x). The graphical interpretation (refer back to Figure 3-3) is that for any given budget line parallel to the original one (and to the right of it), the host will select the point of tangency with the highest possible indifference curve. For instance, when the host receives income B-A in Figure 3-3 (which would be the net incremental cost of the move from q_d to q)it will choose conservation level q_h. Formally, the problem is analogous to *1*, except that the income available to the Host is now given by b+t(q). The host's new problem thus reads:

$$\operatorname*{Max}_{x,q}\ u(x,q) \quad s.t. \quad p_x x + p_q q \;=\; b + t(q) \tag{13}$$

When the host is transfer taker, it maximizes its own utility subject to the budget b *plus* the transfer ***t(q)***. The transfer t(q) is defined as the amount of income in excess of the resources available domestically that would induce the host to choose, in an unconstrained fashion, conservation level q. It follows that:

$$t(q) \;=\; e(q) - b \qquad \Rightarrow \qquad t(q) \;=\; T(q)\big|_{\gamma=0} \tag{14}$$

That is, the transfer taking behaviour can be analyzed with the quantity taking model provided that γ is set equal to zero, i.e. provided that incremental cost is being paid gross. So we can define the transfer-taking solution as $q_{\gamma 0}$. A natural question is whether the host will be better off choosing the quantity-taking, rather than the transfer-taking strategy. One would suspect that the transfer-taking option, which entails optimizing bahaviour, will be preferable to the transfer-taking solution, that induces the host to a quantity-constrained, and hence sub-optimal, behaviour. However, the transfer-taking solution depends upon the additional amount of resources that ROW decides to make available, on which the host has no control. If this amount is small, so will be the utility gain that the host will achieve vis a vis the initial welfare level in the domestic equilibrium. By introducing explicit specifications for the utility functions, it is possible to see cases where the quantity-taking strategy dominates the transfer-taking behaviour in terms of welfare improvements of the domestic equilibrium. An example of this possibility is provided in section 3.3.2.

3.2.5. Allowing For Price Distortions In The Host Country

The model has so far assumed that the prices p_x and p_q correctly reflect the social scarcity values of goods x and q in the host country. However, for many developing countries hosting biological resources, this assumption may not be appropriate.

Typically, there will be two, often coexisting, type of distortions[12]. The first source of distortions regards the price of good x. In many cases, consumption of the non-environmental good x will be encouraged by governments of host countries because of its beneficial effects on growth, or because of concerns about poverty. In this case the true social scarcity cost, p_x, will be lowered of a subsidy factor δ_x.

[12] The existence of external economies and diseconomies is often conceptualized in the literature by a divergence between private and social marginal benefits. The analysis in the text focuses on cost; this is for reasons of consistency with the approach of this paper, where the mechanism for internalizing trasboundary externalities of conservation depends on the expenditure function of the host. As explained in the text, this, in turn, is affected by changes in the cost of purchasing goods x and q, caused by price distortions.

Regarding q, it is often argued that conservation levels are suboptimal not only internationally, but also from the developing country point of view. There are both equity and efficiency reasons to argue that developing country should conserve more of their biodiversity. In terms of equity, the "sustainable use industry" (e.g. agroforestry, non timber forest products) is often associated with sectors of the economy which are marginalized both geographically (poorly accessible areas) and socially (indigenous people). Geographic remoteness and inadequate access to market channels are likely to result in high production costs and competitive disadvantage vis a vis other, non conservation compatible industries. A way to improve the living conditions of people living in marginal areas would be to improve the market prospects of their sustainable industries.

In terms of efficiency, it is often argued that sustainable use activities generate locally ecological benefits (watershed protection, micro-climate stabilization). To the extent that these benefits are not internalized by the sustainable use industry, less incentives for conservation will prevail.

In terms of the present analysis, we can capture both effects by augmenting the "correct" price, p_q, with a distortion factor $(1+\delta_q)$, with $\delta_q > 0$. The resulting price, $p'_q = p_q(1+\delta_q)$ will be higher (and therefore demand for q in equilibrium lower), both because of higher production and transaction costs in the sustainable use industry, and because producers are unable to reduce those costs by capturing the social benefits of their activity.

In principle, domestic public policy can lower δ_q either, on equity grounds, by improving market access for marginal sustainable producers; or, on efficiency grounds, by introducing internalization mechanisms, e.g. charging off-site water users for ecological services provided upstream by sustainable producers.

Taken together, the two distortions will modify the budget constraint as follows:

$$p_x(1-\delta_x)x + p_q(1+\delta_q)q = b; \qquad 0<\delta_x<1; \qquad \delta_q>0 \qquad \textit{15}$$

With respect to the present model, the qualitative effect of introducing distortions into the host's budget constraint will be that the domestic optimum will be characterized by a lower level of q and higher level of x compared to the situation without distortions. Depending on its preferences, the host may be better or worse off than in the no-distortions case, whereas ROW will surely be worse off, as it will be quantity-constrained to a lower level of conservation. An interesting question is whether this effect on the baseline will also alter the host's and ROW's incentives for negotiating an increased provision of conservation on the basis of an incremental cost scheme. Some insights can be gained by imposing specific forms onto the utility functions of host and ROW, and carrying out some numerical and diagrammatic simulations. This is the objective of next section.

3.3. SOME RESULTS USING PARTICULAR FUNCTIONAL FORMS

Let us impose some specific functional forms on the utility functions of the Host country and of the Rest of the World. In order to get tractable algebraic derivations in presence of non-linearities in the budget constraints, we have supposed that utility for both parties is multiplicative in both commodities:

$$u(x,q) = xq; \qquad U(X,q) = Xq \tag{16}$$

3.3.1. Domestic optimum, quantity and transfer taking solutions

It can be easily shown that the domestic optimum is given by ($v_d(\cdot)$ indicates indirect utility):

$$x_d = \frac{b}{2p_x}; \qquad q_d = \frac{b}{2p_q} \qquad v_d(b,p) = \frac{b^2}{4p_q p_x} \tag{17}$$

The quantity constrained optimum of ROW is:

$$X_d = \frac{B}{p_x}; \qquad V_d(B,b,p) = \frac{Bb}{2p_q p_x} \tag{18}$$

When the host is quantity taker, the problem for ROW becomes:

$$\underset{X,q}{\mathrm{Max}}\, Xq \qquad s.t. \qquad p_x X + (2-\gamma)p_q q + \gamma\frac{b^2}{4p_q q} = B+b \tag{19}$$

To see how, from expression *7*, which applies to the general case, one arrives to expression ***19***, which applies to this particular case, note the value that the terms defined by Equation 5 take on when utility is multiplicative:

$$e(p,\phi(q)) = 2pq; \qquad \tilde{e}(p,u_d,q) = \frac{b^2}{4p_q q} + p_q q \tag{20}$$

Also, note that $e(p, u_d)$ is equal to $\boldsymbol{b}$ by definition. The solutions to this problem can be shown to be:

$$q_\gamma = \frac{(B+b)}{2(2-\gamma)p_q}; \qquad X_\gamma = \frac{(B+b)^2-\gamma(2-\gamma)b^2}{2(B+b)p_x};$$
$$x_\gamma = \frac{(1-\gamma)[(B+b)^2+\gamma b^2(3-\gamma)]+\gamma b^2}{2(2-\gamma)(B+b)p_x} \tag{21}$$

Notice that for $\gamma=1$, we in fact get $q_\gamma=q_g$, and $x_\gamma+X_\gamma=(x+X)_g$, i.e. the equilibrium values in the quantity-taking case coincide with the global optimum.

Plugging these values back into the host's utility function, we obtain an indirect utility function with prices, incomes, and the clawback factor γ as arguments:

$$v(B,b,p,\gamma) = \frac{b^2\gamma^3-(B^2+4b^2)\gamma^2+(3b^2-2Bb)\gamma+(B+b)^2}{4(\gamma-2)^2 p_q p_x} \tag{22}$$

Differentiating this expression with respect to γ, and, to simplify the algebra, expressing prices in terms of p_q and incomes in terms of b (i.e. letting p_q=b=1), we get:

$$\frac{\partial v}{\partial \gamma} = \frac{\gamma^3+(B^2-6)\gamma^2+(2B+13)\gamma-8}{4(\gamma-2)^3 p_x} \tag{23}$$

By equating the numerator of that expression to zero, we get an equation of third degree, which admits three roots: two complex, and one real. Discarding the complex roots, we obtain:

$$\gamma^{*} = 2 - \frac{(B+1)^{2} + 9\,M^{2}}{\sqrt{3}\,M}; \qquad\qquad 24$$
$$M = \left(\sqrt{3}\left[(B+1)^{4}(B^{2}+2B+28)\right]^{1/2} - 9(B+1)^{2}\right)^{1/3}$$

where γ^{*} is expressed in terms of B, which, as b is the income numeraire, has the interpretation of the relative difference in income between ROW and host. We can plot the optimal clawback factor against B, as in Figure 3-5.

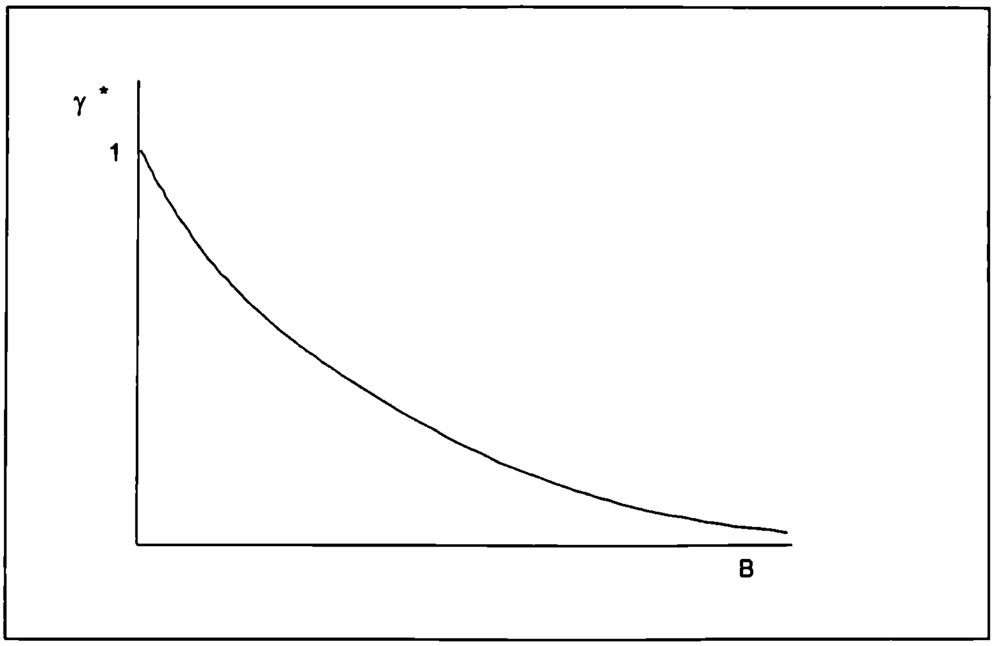

Figure 3-5 Optimal calwback factor

The larger the relative difference in incomes, the lower the optimal clawback factor, and the closer the equilibrium transfer to gross incremental cost. Interpretation: when the income differential is small, the size effect dominates, and γ^* is close to 1; at high income differentials, the slice effect dominates, and γ^* approaches zero. When there is little international finance available for conservation, there will be little scope for diverting part of it from outright conservation to increasing the well-being of the host.

By claiming a large share of incremental benefits, the host loses in terms of reduction of the cake's size more than it gains in terms of increase in its slice. Conversely, when ROW makes more finance available, the host will be able to get a larger slice (i.e. a lower γ) without affecting the overall size of the cake too much.

Will the host do better under quantity or transfer taking behaviour? According to the above analysis, the transfer taking solution can be obtained by imposing $\gamma=0$ onto the quantity taking solution. As shown in Figure 3-5, $\gamma=0$ is an optimal choice from the point of view of the host only when the difference in relative incomes approaches infinity. Therefore, we can infer that for finite values of B, the host is better off under quantity, and not transfer, taking behaviour.

3.3.2. Domestic optimum vs. incremental cost financing

While it is intuitively clear that ROW has an incentive to enter into a negotiation with host to move away from its baseline quantity constrained equilibrium (as illustrated in section 3.2.1), why would the host embark in a bargaining process, when the baseline situation is already an optimum for it?

Indications have been obtained for the multiplicative utility case by carrying out some numerical analysis of the model with the software Mathenatica 2.0. Such an analysis confirms that the answer is gains from trade: both parties are better off with the ICS than with the domestic optimum. By inserting the optimal value γ^* into the indirect utility function $v(\bullet)$ we can express the latter in terms of relative prices and relative incomes only: $v_{\gamma *}(B, p_x)$. And similarly for ROW's indirect utility function: $V_{\gamma *}(B, p_x)$. (Again, p_q and b have been set equal to unity).

For both Host and ROW, we can plot the ratio of indirect utilities obtained in the two situations, $v_{\gamma *}/v_d$ and $V_{\gamma *}/V_d$, as a function of relative incomes (or as a function of B only, when b is normalized to unity). As shown by Figure 3-6 both curves exceed unity for all values of B>0.

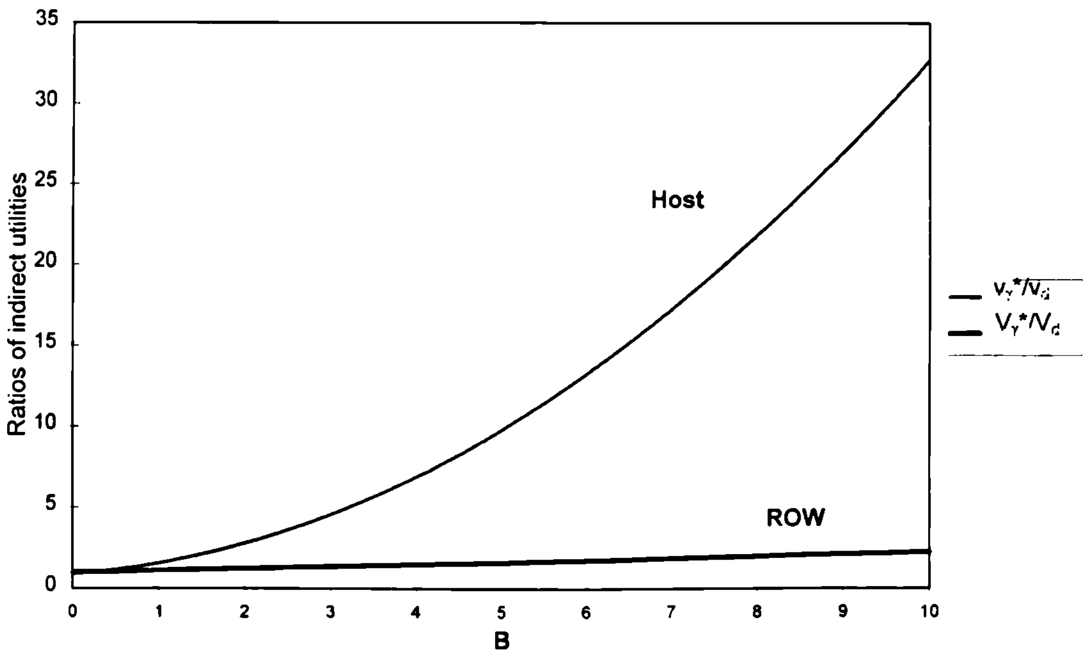

Figure 3-6 Domestic optimum vs. incremental cost financing

3.3.3. Price distortions

Case a): Host and ROW agree on the baseline

This result that ICS dominates the domestic optimum still holds in the case of price distortions, if these are present both in the baseline domestic optimum and in the alternative ICS: the graph of Figure 3-6 would not be modified by the inclusion of the distortion coefficients. In other words, if host and ROW agree on the baseline (be it distorted or undistorted), they will also both be willing to adopt ICS.

Case b): Host and ROW disagree

However, host and ROW may not necessarily agree on whether or not distortions should be included in the baseline[13]. ROW, for example, could argue that ex art. 11 of the Biodiversity Convention, developing countries have an obligation to introduce incentives for biodiversity conservation, which would also include the elimination of existing disincentive for conservation, like price distortions. In this case, ROW may not be willing to negotiate an ICS unless distortions are previously removed in the host country. If this is the case, however, the host will still evaluate the attractiveness of the ICS with reference to the distorted domestic optimum, which is for its purposes the significant baseline.

Therefore, a separate numerical analysis of the model has been carried out, to compare the attractiveness for each of the two parties of the two alternatives: distorted domestic

[13] See the discussion at the end of this section for an overview of the policy and political issues involved in reaching agreement on the baseline.

optimum, undistorted ICS. To obtain results visualizable in a two-dimensional space, we picked two key parameters (relative incomes and distortion factor affecting conservation). We then constructed the locus of values of the parameters where each party is indifferent between the two schemes under consideration, i.e. where the ratio of indirect utilities is equal to unity. For values of the parameters outside of that locus, one scheme will dominate the other. If the region of dominance of a given scheme is the same for both parties, then in that region there will be "consensus" on the relative attractiveness of that scheme.

The results are provided in Figure 3-7, which depicts the two parties' curves of indifference between undistorted ICS and distorted domestic optimum in the B - δ_q space.

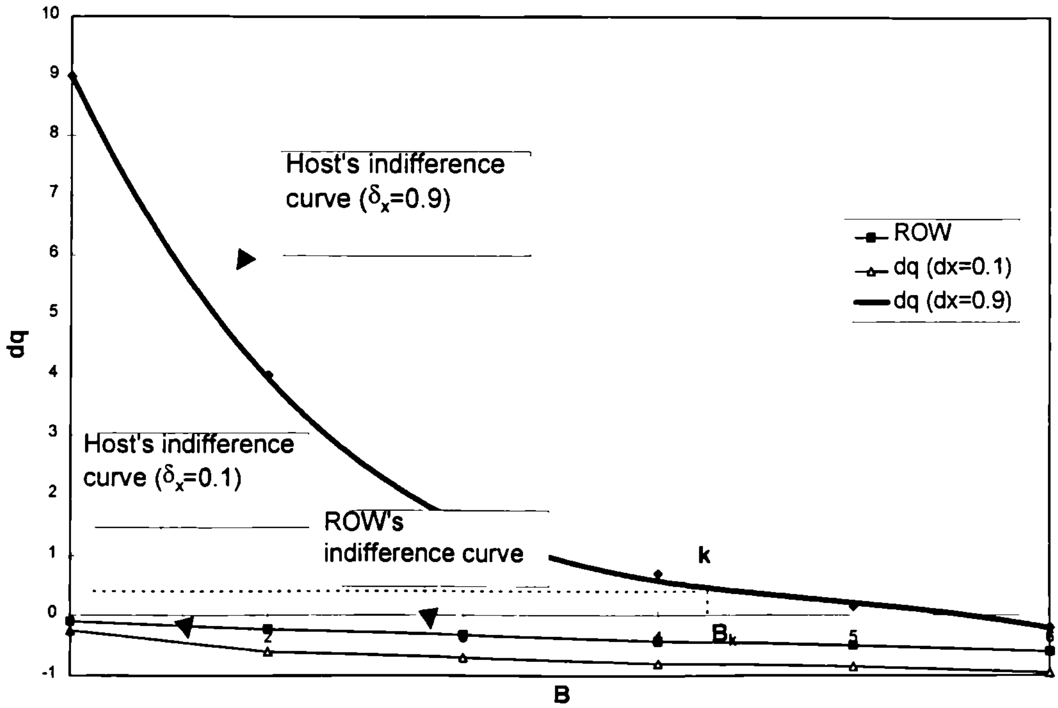

Figure 3-7 The case of price distortions

The intermediate line is ROW's indifference curve; the upper and lower lines are the host's indifference curves for values of δ_q=0.9 and δ_x =0.1, respectively. Above the relevant indifference curve, each party is better off with the undistorted ICS; below it, with the distorted domestic optimum.

For any $\delta_q > 0$, ROW is always better off by paying the undistorted transfer. The host, however, will be better off in the domestic optimum when δ_x is high. For instance, the host will prefer the distorted domestic optimum for all values of the parameters below the upper curve, if $\delta_x = 0.9$. The indifference curve of the host gives us an idea of the kind of incentives necessary for it to accept an ICS negotiated on the basis of an undistorted baseline.

For example, when $\delta_x = 0.9$ and $\delta_q = 0.5$ (point $\boldsymbol{k}$), conservation finance of at least $\boldsymbol{B_k}$ is required for the host to accept an undistorted ICS. Any amount less than $\boldsymbol{B_k}$ will make the host better off with the distorted baseline, and therefore unwilling to enter an ICS scheme. The diagram also confirms the intuition that incremental cost funding will be made cheaper by domestic policies aimed at supporting the "sustainable use" industry, or by policy reforms that reduce pricing distortions in the rest of the economy.

Policies of the first type would result in a lower δ_q , which would permit an upward movement along a given indifference curve; policies of the second type would result in lower δ_x, and hence a downward shift of the relevant indifference curve. In both case, lower levels of financial commitment from the international community would be needed, other things being equal, to induce the host to choose higher conservation levels, to be funded by an incremental cost system.

Discussion

Conservation of biological diversity depends upon both domestic policy reform and upon the financial support of the international community. The appropriate way in which this two types of efforts should be combined is a complex issue, which would probably deserve to be dealt with separately. The diagrammatic analysis presented above has illustrated the type and direction of the incentives at work. A more systematic treatment of the issue would necessitate spelling out the sequential decision trees faced by host and ROW, specifying the payoffs resulting from alternative strategies, and, for those branches of the host's decision tree where policy reforms are present, modelling cost and benefits to different domestic stakeholders of those reforms.

In the present context, however, it may be interesting to discuss a few policy issues. The connection between international funding for conservation and pre-existing domestic disincentives has long been a hotly debated topic, with significant political ramifications in the international negotiation arena.

On the one hand, a large body of the literature (Repetto and Gillis, 1988, Pearce and Warford, 1993) points to the key role played over the last few decades by developing countries' credit, fiscal and pricing policies in generating negative incentives for natural resource management in general, and biodiversity conservation in particular.

On the other hand, developing countries have quite often asserted in a number of negotiating fora (Earth Summit, Convention on Biological Diversity, GEF Council) that the principle of "additionality" -which implies that resources over and above conventional aid flows should be mobilized to tackle the new global environmental issues, and which underpins for example the establishment of the GEF-, should not result in "new conditionality".

To balance off these tensions, a number of compromise statements have been incorporated in international legal and policy documents. The Biodiversity Convention, for example, while calling contracting parties to undertake measures "that act as incentives for the conservation and sustainable use of components of biological diversity" (art. 11), reaffirms that "States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies" (art. 3).

The GEF council, in approving the overall policy on incremental cost, has recommended that in implementing it "the notion of "environmental reasonableness" be a guiding principle so as not to penalize progressive environmental action in recipient countries" (Global Environment Facility, 1995).

However, the relationship between developed and developing countries in the area of policy reform need not be necessarily antagonistic. There may well be sectors of developing country societies (indigenous people, NGOs, academics) that would actually support policy measures promoting sustainable uses of natural resources compatible with conservation; in some cases policy reforms are not undertaken because of infra-government coordination problems, or because of the lack of a systematic framework for assessing the impact of the various sectors of the economy on the conservation of natural resources.

The international community may effectively promote conservation by facilitating the process of policy reform, and more generally the process of integrating global environmental concerns into sectoral development planning (World Bank, 1995). Seed money could be used to promote stake holder dialogue and improve their understanding of the economy-environment interactions. This, of course, opens up a fascinating and mostly uncharted area for theoretical and applied research. Regarding the latter, the issue of promoting the establishment of a progressive environmental baseline will be addressed by the case study of this dissertation (section 6.3.6).

3.4. CONCLUSIONS

By ratifying the Convention on Biological Diversity, the international community has taken substantial commitments towards conservation of biological resources. The convention also recognizes that a major share of the resulting financial burden must be borne by the rich nations.

However, the formulation of the financial provisions of the Convention has been left in vague terms. The compromise incorporated in the phrase "full agreed incremental cost" reflects the tension between developing countries' claims that there is little for them to gain from conservation, and developed countries aversion to fund baseline development activities, rather than conservation.

The present model, by providing a particular interpretation to the financial provisions of the Convention, has indicated a way in which those conflicting interests can be balanced. It has been shown that both ROW and host will have incentives for agreeing on a transfer of resources that entails only partial deduction of domestic incremental benefits. This transfers, despite failing to reach the utilitarian global optimum, still represents a Pareto improvement over the pre-convention status quo.

By imposing a particular multiplicative functional form on the utility of both host and ROW, additional results can be obtained. It has been shown that the optimal transfer implies a clawback factor decreasing with relative income differentials, and that incremental cost financing dominates the domestic optimum even when price distortions are present in the host country. If removal of price distortions are a precondition for incremental cost funding, the analysis has illustrated the magnitude of incentives necessary for the host to give up the distorted baseline.

Theoretically, the indeterminacy of the Convention can be resolved straightforwardly with some simple analytical tool, as suggested by this chapter. However, it is quite likely that efficiency arguments like those put forward here are not the only ones that matter in the search for agreements on the way to fully implement the Convention. Other considerations (equity, strategic behaviour, pay-offs at stake in other negotiating tables), will also play an important role in the appropriate institutional and policy fora.

Annex 3-1: Deriving α and β

The expenditure function $e(p_x, p_q, u)$ can be also be defined as a function of ***q***: that is, what is the minimum expenditure necessary to optimally choose conservation level q at given prices? We know that at the optimum, it must be true that:

$$\frac{u_q}{u_x} = \frac{p_q}{p_x} \tag{25}$$

This condition implicitly defines ***x*** as a function of ***q***: x=x(q). We can thus substitute in the expression of the budget constraint:

$$p_x x(q) + p_q q = e(p_x, p_q, q) \tag{26}$$

The derivative with respect to ***q*** of the expenditure function defined in this way is:

$$\frac{\partial e}{\partial q} = p_x \frac{dx}{dq} + p_q \tag{27}$$

The derivative dx/dq can be obtained by totally differentiating 28 above:

$$\frac{u_x u_{qq} - u_q u_{xq}}{(u_x)^2} dq + \frac{u_x u_{qx} - u_q u_{xx}}{(u_x)^2} dx = 0 \tag{29}$$

which gives the expression of α reported in the text:

$$\frac{dx}{dq} = \frac{u_q u_{qx} - u_x u_{qq}}{u_x u_{qx} - u_q u_{xx}} = \alpha \qquad 30$$

Regarding the constrained expenditure function, $\tilde{e}(p_x, p_q, u_d)$ this can also be expressed as a function of q: at given prices, what is the minimum expenditure that keeps the host at the initial level of utility u_d while conservation is at level q? When utility is constant, i.e.:

$$u(x,q) = u_d \qquad 31$$

x is implicitly defined as a function of q: $x = \tilde{x}(q)$. Substituting into the budget constraint, we get:

$$p_x \tilde{x}(q) + p_q q = \tilde{e}(q) \qquad 32$$

The derivative of the constrained expenditure function with respect to q is then:

$$\frac{d\tilde{e}}{dq} = p_q + p_x \frac{d\tilde{x}}{dq} = p_q - p_x \left. \frac{u_q}{u_x} \right|_{u=u_d} = p_q - p_x \beta \qquad 33$$

where the derivative dx/dq has been calculated by totally differentiating condition 31.

Part III - Biodiversity loss and conservation in practice: a case study in Mexico

Introduction to part III

Part 1 of the dissertations has discussed some of the key conceptual, definitional and methodological issues of the debate on biodiversity conservation. Part 2 has provided theoretical analysis of two of the issues introduced in part 1: causes of loss and funding of mitigation activities. In particular, chapter 2 has identified and discussed social and economic factors responsible for land use change processes likely to result in biodiversity loss. Chapter 3 has proposed a model for analyzing the functioning of the main tool for conservation funding (incremental cost) used in the context of the Convention on Biological Diversity.

Part 3 of this research addresses issues of land conversion, biodiversity loss and options for conservation in a real-life case study. Part 3 consists of three chapters. Chapter 4 introduces the case study area: Sierra de Santa Marta, located in the southern part of the State of Veracruz, Mexico. Chapter 5 discusses the social and economic factors that have been responsible over the last few decades for various processes of land us change and depletion of biological resources in the study area, as well as proposing a model for simulating further impacts over the next couple of decades. Finally, chapter 6 develops a model for aggregating farm decisions over space and time, and discusses options for a biodiversity conservation and management strategy which would tackle the causes of change analyzed in chapters 4 and 5.

4. The area: Sierra de Santa Marta (Veracruz, Mexico).

This chapter provides essential information on the Sierra de Santa Marta (SSM), the area selected[1] for the empirical part of the dissertation.

4.1. Location and physical description

In macroregional terms, the Sierra de Santa Marta (SSM) lies on the Gulf of Mexico, about 150 kilometers to the southeast of the Port of Veracruz, in the western foothills of Lake Catemaco, and about 40 kilometers to the northwest of the cities of Coatzacoalcos and Minatitlán. Administratively, it belongs to the municipalities of Catemaco, Mecayapan, Soteapan, and Pajapan. It is also identified as Sierra de Soteapan in various sources.

SSM belongs to a broader physiographic structure known as Mountainous Volcanic System of Los Tuxtlas. The name "Los Tuxtlas" refers to an area that includes the three volcanoes of San Martin Tuxtlas, Santa Marta and San Martin Pajapan. The last two (which correspond to the better preserved portion of Los Tuxtlas) are included in the present study area, whereas the first one is not.

The coordinates of Sierra de Santa Marta are 18° 05' and 18° 33' north latitude and 94° 37' and 95° 03' west longitude. Its natural boundaries are the Gulf of Mexico on the north and east, the depression of the Sontecomapan lagoon to the northwest, Lake Catemaco to the west, the Veracruz coastal plain to the south, and the Ostión lagoon to the southwest (see Figure 4-1).

The area covers 135,912 hectares[2], of which 82,300 hectares were declared a protected forest and wildlife refuge zone under the decree of April 28, 1980. In 1988 it was reclassified as a special biosphere reserve. The boundaries of the present study area were defined by combining criteria related to land tenure, and the need for a territorial and hydrographic continuum. The zone contains 90 land units, including communities, ejidos, and private properties (see section

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[1] The reasons explaining the choice of the study area have been addressed in the acknowledgment section.

[2] This makes for approximately half of the broader Los Tuxtlas region, although there is not a unique definition of what is the area covered by the latter. Several sources indicate the size of Los Tuxtlas as ranging around 250,000 hectares.

4.3.2 for clarifications on land tenure categories); among towns, villages and other forms of human settlements, the total number of centers of residence is 110.

In the eastern and north hillsides, the rainfall reaches 6,000 mm in annual average (in the highest elevations), and decreases gradually along lowers altitudinal gradients: in the southwest a minimal rainfall of 1,300 mm. in annual average is recorded, so that three humidity provinces are therefore found in the SSM: Wet, Very Wet and Rainy.

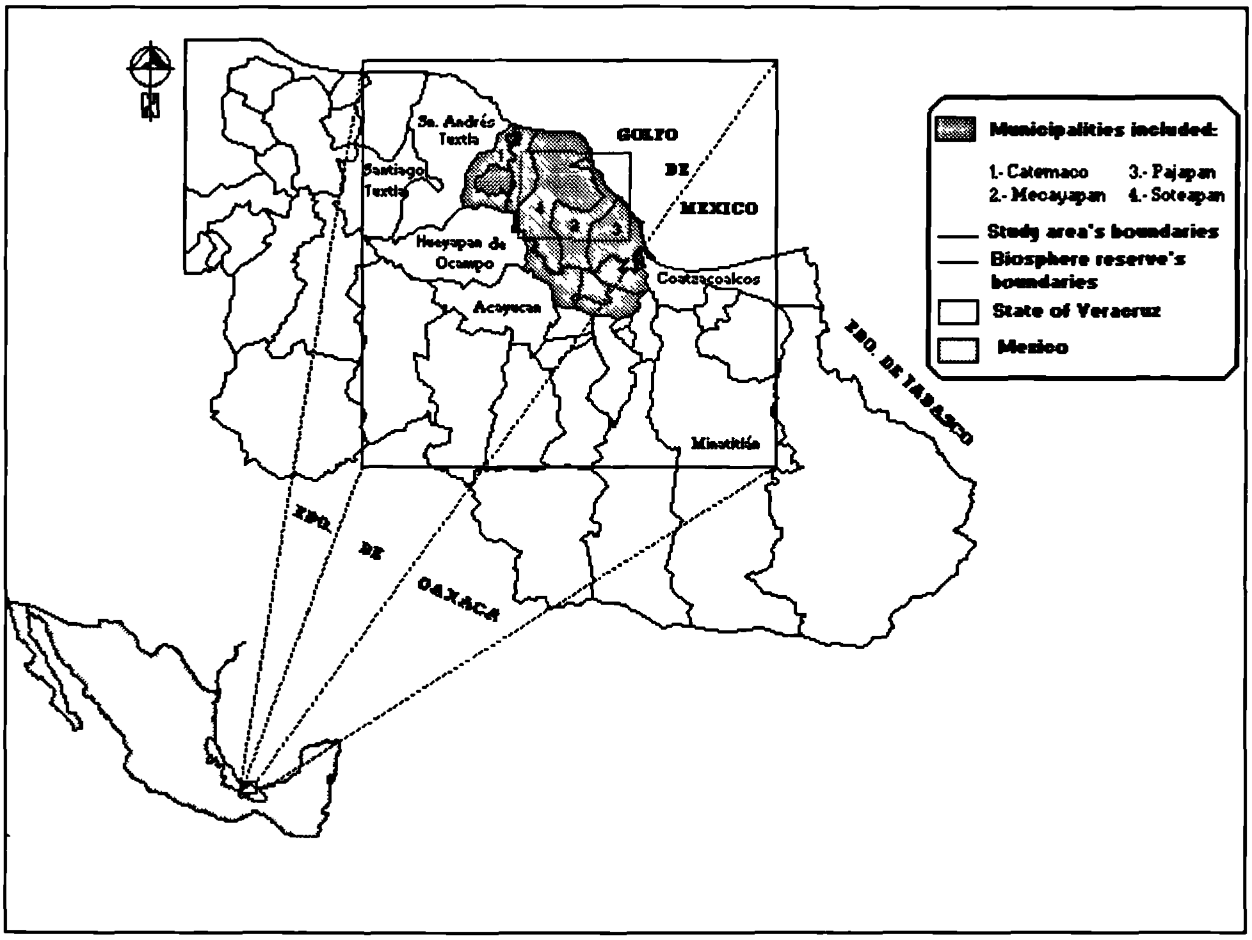

Figure 4-1: Location of the study area (Source: PSSM, 1995)

4.1.1.1. Zoning

This sub-section introduces a subdivision of the study area into ecological and socio-economic zones. This is instrumental to the rest of this chapter, since in several cases the presentation of the socio-economic data under consideration will feature break-downs by zones.

The proposed zoning is based on ecological, geographical and land tenure considerations, and is the result of previous extensive cartographic and ground-truthing work undertaken by the PSSM in the early 90s[3]. In accordance with broad UNESCO methodological guidelines on biosphere reserves, three basic zones are identified: (i) a nucleus or core zone, (ii) a buffer zone, and (iii) a zone of influence. Figure 4-2 shows the distribution of these three zones in the region. The characteristics of the zones proposed for the Sierra de Santa Marta are summarized below.

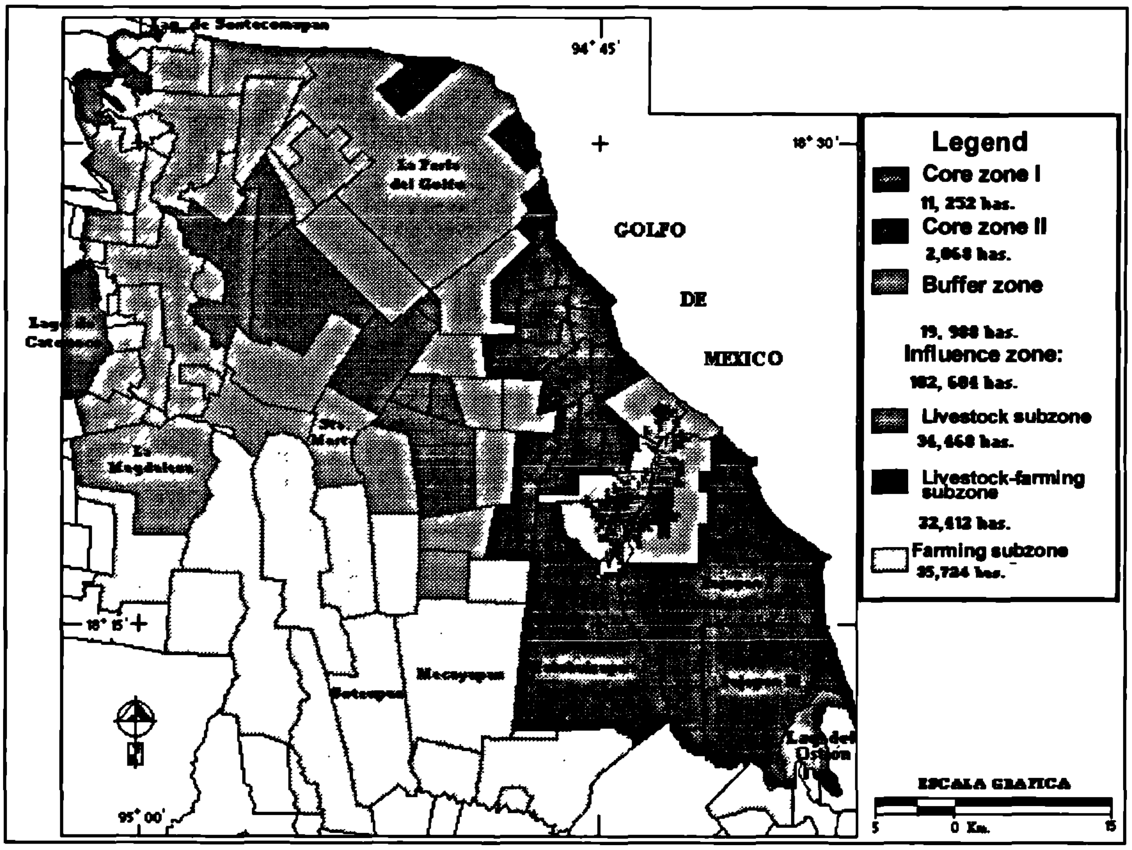

Figure 4-2: zoning of the study area (Source: PSSM, 1995, Pare et al., 1993)

· Nucleus zone; it includes areas that best conserve their natural conditions and cover sufficient land to allow for the maintenance of biotic communities and the ecological processes to sustain them.

· Buffer zone. This includes human settlements, farming and livestock areas, as well as a significant forested area component, which protects and mitigates the effects of human

[3] In the intentions of its developers, the zoning should also be instrumemental to the implementation of the

activities in the core zone. The buffer zone offers additional space for conservation of species and local migratory movements of fauna.

· Influence zone. This area includes most of the largest population centers of the study area. Resident population interact in various ways with communities and natural resources of the buffer zones, and in some cases with the nucleus zone as well. The influence zone includes natural or modified areas devoted to activities such as agriculture, livestock, gathering, hunting, forest exploitation, and fishing.

The fate of some of SSM's most valuable biodiversity will be by and large dependent on land use decisions taken in the core and buffer zones. Nevertheless, there are good reasons to include the influence zone too into the analysis. First, the influence zone still features scattered areas covered by vegetation types (primary forest fragments, second growth forest, coffee groves) that can complement the protection function of the buffer zone. Second, buffer and core zones are connected to the influence zone through a web of social and economic linkages, including land tenure and migration patterns, exchanges of goods and labor, so that an analysis of land use decisions constrained to the buffer and core zones is unlikely to be complete.

Within the influence zone, there is a broad natural, cultural, social and economic diversity that must be taken into account for analysis purposes. A subzoning of the zone of influence is therefore proposed, with the idea of delimiting spaces that share common characteristics and problems. The subzoning, also shown in Figure 4-2, includes:

a) Livestock zone, consisting of 34,540 has located to the west and north of the study area. This zone includes 22 territorial units where individual rather than communal ownership is predominant and the population of mixed race is more numerous than the indigenous population. Grazing land occupies 80% of the working surface and only between 2% and 7% of the total area is dedicated to agriculture.

b) Farming/livestock subzone, consisting of 32,644 has with 17 land tenure units, all communally owned with predominant indigenous population. It is characterized by land uses with large areas

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protected status of the region, formally decreed in the 1980s but never enforced in practice.

under pasture (73%) and agriculture systems (25%) based on the combination of maize-secondary growth vegetation.

c) Farming subzone. This subzone encompasses 36,056 has and is comprised of 13 communal lands units. Predominant in these communities are agricultural activities such as the traditional cultivation of maize, beans, and shaded coffee. The presence of livestock activities and salaried work is far less significant than in the other two portions of the influence zone.

The categorization of land in zoning units overlaps with the administrative division of the study area across municipalities, as illustrated by Table 4-1. This double system of classification, which will be used repeatedly throughout the rest of part 3 of the thesis, is an important one. The zoning classifications can be used for purposes of analysis of trends and of planning alternative scenarios. On the other hand, the administrative classification is especially important for policy purposes: whatever the development strategy may be, this will need to be implemented, politically and institutionally, at the individual municipio level.

Table 4-1 Classification of the study area in zoning and administrative units (Source: PSSM, 1995)

Zone	Municipio	Land units	Area (has)	Area in percent of total	Breakdown of influence zone		
					Farming	Farming livestock	Livestock
Nucleus	Federal land	1	152	0.11%			
Nucleus	Catemaco	1	3,064	2.19%			
Nucleus	Mecayapan	2	740	0.53%			
Nucleus	Soteapan	3	4,248	3.03%			
Buffer	Catemaco	6	6,968	4.97%			
Buffer	Mecayapan	7	6,004	4.28%			
Buffer	Soteapan	7	7,068	5.04%			
Influence	Catemaco	23	17,420	12.43%			12.43%
Influence	Mecayapan	16	36,356	25.94%	8.42%	8.55%	8.97%
Influence	Pajapan	4	20,486	14.62%	4.55%	10.07%	
Influence	Soteapan	20	37,636	26.86%	18.21%	4.67%	3.98%

Access query name: Area by zone and municipio

4.1.2. Sources of information

The material presented in this chapter as well as the analysis carried out in the rest of the dissertation rely on a number of sources of information. These range from census data to official documents to specialized bibliography. In cases where Federal or State programs are mentioned, which at data collection time were still under preparation, information obtained through interviews with public officials or other sources is also used. Data on land areas, land use and vegetation cover was obtained from the Geographical Information System of the PSSM[4].

4.1.2.1. Field surveys

One major source of primary data is the field work carried out in the study area in the context of the GEF-funded case study mentioned in the acknowledgment section. Two types of surveys were undertaken during August and September of 1995. The first survey consisted of interviews with 531 heads of household in 47 communities. The questionnaire comprised questions on household composition, agriculture, forest and livestock activities, as well as fishing, hunting, live animals trapping, and sources of off-farm income. The other type of survey was administered to 74 key informants in 41 communities. In this survey, community-level information was sought on land tenure, land inheritance and parceling modalities, availability of, and access to, rural services and infrastructure. Annex 4-1 reproduces the form used in the household survey.

4.1.2.2. **Household survey: design and sampling criteria**

A general principle of survey-based field work is that survey design and sample determination should be guided by the research and policy interest that motivate the work (Kish, 1989; Scheaffer, Mendenhall, and Ott, 1986). The present case is no exception: as

[4] The Geographic Information System of the Proyecto Sierra de Santa Marta is based on maps at the 1:50,000 scale. Maps have been digitalized using with a grid of 200 metres -per side boxes (equivalent to 4 has per box). Land use data are based on interpretation of 1990 aerial photography and satellite images, and validated through ground truthing exercises. For further dtails, see (Pare, 1993).

explained in the rest of this subsection, the broad objective and the choice of indicators of ecosystem status informed both the design of the questionnaires and the identification of sampling criteria.

The broad objective of the survey was to collect information on a range of demographic, social and economic variables regarded as important in determining individual land users' decisions concerning: a) management of natural resources in general, and b) in particular, decisions considered important in determining future trends in the conservation of the region's biological resources. Several indicators of the status of conservation were considered, the most important of which being the types of land vegetation cover encountered in the study area at data collection time.

The following criteria were adopted in determining the sample for the household survey. The first step was the definition of the population. This consists of holdings included in the study area, as defined in para 4.1 above. The population was then divided in clusters corresponding to land tenure units (private properties and communities), which in turn were assigned to strata corresponding to zoning categories (that is, nucleus, buffer and influence zones), and to municipalities. A multi-stage sampling was conducted on the clustered, stratified holdings. The first stage was the definition of a sample of 47 clusters (land units). In the second stage, a random sub-sample of holdings was selected within the clusters selected in the first stage. In accordance with the broad objectives and choice of indicators described above, first stage sampling was determined with the following criteria.

a) Land units (in all the three zones) with no permanently residing population were not included in the sample;

b) All the (remaining) 17 land units located in the buffer zone were included in the sample;

c) To allocate remaining survey resources to the influence zone, it seemed sensible to use a "probability proportional to size" approach (PPS)(Kish, 1989). Sampling probabilities were made proportional to population. The assumption was that the larger the population, the larger the pressure on forest resources -intended as a proxy for a wider spectrum of biological resources- be those located in the community of residence or in neighboring ones[5]. Table 4-2 summarizes the main elements of the first stage sampling process.

Table 4-2 First stage sampling: selection of land units

Zone	Municipio	Total units in study area	Total units with permanently residing population	Total units sampled	Percentage of population in sampled units
Buffer	Catemaco	7	4	4	1.65%
Buffer	Mecayapan	7	6	6	1.97%
Buffer	Soteapan	7	7	7	2.12%
Influence	Catemaco	22	15	5	1.58%
Influence	Mecayapan	16	16	8	25.21%
Influence	Pajapan	4	4	2	13.55%
Influence	Soteapan	20	20	15	21.94%
Total		83	72	47	68.03%

The second stage sampling consisted of selecting random samples of holdings in each of the land units selected in the first stage. Once again, a broad principle that guided the allocation of survey resources in this stage was to give special consideration to the buffer zone. Subject to this overall priority, cost considerations (transport, accessibility, etc.) dictated the choice of the individual sub-sample sizes. The total number of head of household interviewed was 531, with broad distribution over zones and municipios summarized by Table 4-3.

Table 4-3 Second Stage sampling: sample sizes across zones and municipios

Zone	MUNICIPIO	Population	Sample	House-holds	Sample/ population	Sample/ households
Buffer	Catemaco	976	56	160	5.74%	40.33%
Buffer	Mecayapan	1,164	36	201	3.09%	23.65%
Buffer	Soteapan	1,251	48	261	3.84%	19.91%
Influence	Catemaco	929	33	193	3.55%	22.17%
Influence	Mecayapan	14,867	110	2,322	0.74%	14.95%
Influence	Pajapan	7,991	30	1,358	0.38%	2.28%
Influence	Soteapan	12,941	218	2,462	1.68%	16.41%
Total		40,119	531	6,956		

[5] Fuelwood and a number of other forest products are often gathered in communities adjacent to othe one of residence, especially if forest cover in the latter has been cleared.

4.1.2.3. Estimation

Survey data was used to obtain sample means, totals, and proportions, as well as estimators of the same quantities for the population of the study area. In order to calculate population estimates, the following methodology (Scheaffer, Mendenhall, and Ott, 1986) is used in the rest of the chapter, unless otherwise indicated.

For the generic variable y, the notation y_{ij}^{k} indicates the observation coming from household ***i*** located in land unit (or cluster) ***j***, which belongs to stratum ***k***. There are seven strata, (i.e., k=1...7), with number of clusters in each stratum listed by Table 4-2. For stratum k, the number of clusters in the sample and in the population is, respectively, n^k and N^k; similarly, for cluster i, belonging to stratum k, the total number of household is m_i^k and M_i^k. The sample mean of variable y in cluster i, belonging to stratum k is:

$$\bar{y}_i^k = \frac{\sum_{j=1}^{m_i^k} y_{ij}^k}{m_i^k}$$

For stratum k, unbiased estimators of populations mean and total are given by:

$$\bar{\mu}^k = \frac{N^k}{M^k} \frac{\sum_{i=1}^{n_k} M_i^k \bar{y}_i^k}{n_k}; \qquad \bar{\tau}^k = M^k \bar{\mu}^k$$

Equation 4-1

The estimator used for the proportion of the population with a given attribute is:

$$\hat{p}^k = \frac{\sum_{i=1}^{n_k} M_i^k \hat{p}_i^k}{M^k}$$

Equation 4-2

where $\hat{p}_i^k$ is the proportion of household sampled in cluster ***i*** belonging to stratum ***k*** in possess of the given attribute.

4.2. Summary of the components of biodiversity

4.2.1. Diversity of habitats

The coastal location, the orographic complexity, the isolation from other moist jungles, the extensive range of altitudes, and the succession of climate and vegetation bands, among other factors, make for a very wide variety of habitats, running from coastal, lake, and shoreline, to lowland and mountain forests, apart from the disturbed and agricultural areas.

The sierra has five life zones and three transitions (see Table 4-4), based on the Holdridge bioclimatic classification (1967). It contains an impressive gamut of ecological diversity.

Table 4-4: Life zones in Sierra de Santa Marta

Base floor
1. Very moist forest
2. Moist subtropical forest
3. Rain forest
Low mountain floor
4. Very moist forest
5. Subtropical low mountain rain forest

4.2.2. Types of plant life

Los Tuxtlas is the northernmost jungle on the American Continent (Dirzo y Miranda, 1993). This means that the biota is rich in number and quality, owing to the concurrence of species of tropical and boreal origin and species that are native to the region and exist there alone (Ibarra - Manriquez & Sinaca Colin, 1995; Ramirez, 1984; Wendt, 1993). The Sierra contains the widest variety of ecosystems, communities, and organisms typical of the Los Tuxtlas region and of the biogeographic province of the coastal plain of the Gulf of Mexico(Rzedowski, 1978).

4.2.3. Biological wealth

4.2.3.1. Plants

The Sierra exhibits significant plant biodiversity, mostly with neotropical affinity and a substantial component of isolated and residual mesoamerican and neartic elements, many of which are native. Some 1,300 species of vascular plants have been recorded (Ramirez, 1984) out of an estimated flora of over 2,000 species (Sousa and Vázquez-Torres, personal communication). These species belong to 143 families and 607 genera of vascular plants, which represent 66% and 31.4% of all families and genera reported for Veracruz (Ecology Institute, 1995). In Sierra de Santa Marta in particular, and in the Los Tuxtlas region in general, 26 of the 41 native species of trees growing over 18 meters high present in the moist jungles of the Gulf and the Caribbean divide of Mexico are to be found(Wendt, 1993). This is the equivalent of 62% of the woody plants native to Mexico studied by that author. The destruction of habitats and over-exploitation, in some cases, threatens numerous species of plants including various species of *Chamaedorea*, some of which are native or rare such as *C. hooperiana*, *C. tuerckheimii*, and *C. tenella*.

4.2.3.2. Animals

The fauna is as rich as the flora. The bird population is one of the most varied in the country and includes 405 species, counting resident and migratory birds(Winker, Oehlenschlager et al., 1992), or 40% of the 1,010 species of birds recorded in Mexico. The birds in this region are rare owing to ecological isolation and special environmental factors (Edwards & Tashian, 1959; Andrle, 1964; Andrle, 1967). Five subspecies are found only in the region.

There are 102 species of mammals(Gonzalez Christensen, 1986), or 27% of the species recorded nationally, and 66% of those reported for Veracruz. Not including rodents and bats, 83% of the species have been traditionally used for food, medicine, hides, and other uses(Navarro, 1981). There are 43 species of amphibians (9 endemic to the region) and 109 species and subspecies of reptiles (11 endemic to the region) (Morales-Mávil, Pérez

Higareda, and Gónzalez-Romero, 1995). Together they account for 15.6% of the national herpetofauna, which is the richest in the world. In addition, 359 species of butterflies(Ross, 1967), 124 species of odonata (Gonzalez & Villeda C., 1980)and over 50 species of aquatic insects have been found in the different rivers and bodies of water(Bueno, 1980).

4.2.3.3. Endangered species of vertebrates

The most highly endangered species in Los Tuxtlas include animals with larger territorial requirements who may not be able to survive in small islands of forest. This is the case of species such as the jaguar (*Felis onca*), the puma (*F. concolor*), the wild boar (*Tayasu tajacu)*, the ocelot (*Felis pardalis*), the spider monkey (*Ateles geoffroyi*), the paca (*Agouiti paca*), *cabeza de viejo* (*Eira barbara*), birds such as the royal pheasant (*Craz rubra*), the mountain hen (*Tinamu major*), and predator birds such as the crested eagle (*Spizaetus ornatus*) and the harpy eagle (*Harpya harpija*). SEDESOL's records include other species. The green iguana (*Iguana iguana*) and the boa constrictor are on CITES Appendix II as species endangered by illegal trade. A short summary of species recorded, endangered, and endemic is presented in Table 4-5.

Table 4-5: Recorded, endangered and endemic species in the Sierra de Santa Marta and Los Tuxtlas region

Zoological group	Number of species	Endangered species	Endemisms
Mammals (a,b)	102	19	2
Birds(c,d,e)	405	96	6
Reptiles (f,g)	109	23	17
Amphibians(f,g)	43	19	9
Lepidoptera(h)	359	?	5
TOTAL	1015	157	39

Sources: (a)(Gonzalez Christensen, 1986), 1986; (b)(Navarro, 1981); (c)(Winker, Oehlenschlager et al., 1992); (d)(Andrle, 1967); (e)(Ramos, 1982); (f)(Ramirez, Perez - Higareda G. et al., 1980); (g) Morales Mávil, Pérez Higareda y Gonzâlez-Romero, 1995; (h)(Ross, 1967).

4.2.4. Status of biodiversity and biological resources and trends

4.2.4.1. Endangered ecosystems

By 1991, 59,276 hectares of jungles and forests had disappeared out of an original area of 96,640 hectares of wild vegetation existing in 1967 (61.3%).

The most highly endangered ecosystems are those that have been most heavily deforested, and are generally found in low-lying and mid-mountainous areas. They include the moist jungles in low-lying zones (high and medium perennial jungles), mid-mountain mesophilic forests (virtually supplanted by coffee fields and pastures), the mangrove swamps, and the warm climate oak. Fires continue to be a threat to the remaining forested areas[6].

4.2.4.2. Biogeographic significance of the area

The conservation of biological resources of Los Tuxtlas and the Sierra de Santa Marta has state, national and regional importance. In recent years, a very comprehensive assessment of the conservation priorities for the Latin American and Caribbean region has been undertaken by a consortium of the World Bank, WWF and other agencies (Dinerstein, 1995). The study classifies the moist jungles of the Sierra, together with those in other parts of Mesoamerica (broad-leaved humid jungle ecoregion of Tehuantepec) as outstanding on the bioregional level (Central America) or level 1, which is an ecoregion of top regional priority. Therefore, these remnants of rain forest are a high priority for the conservation of regional biodiversity (Latin America and the Caribbean).

Other types of habitats represented in Santa Marta are classified as relevant for the conservation of biodiversity: the warm climate oak forests (Veracruz) and the savannas are classified as critical and important on the local level, with moderate priority on the regional

[6] An evaluation of current land use in the area decreed as a reserve indicates that just 25% of it retains virgin or near-virgin primary forests, and over 8.5% contains secondary growth forest (acahual) and pockets of jungle. Over 30% is occupied by pastures and 28% is used for extensive livestock farming. About 6.7% contains coffee fields, which favor the conservation of biodiversity. See section 4.3.3 for a summary of comprehensive land use data in the region.

scale. The mountain forests are classified as outstanding on the bioregional level, and with high priority on the Latin American scale.

The biodiversity significance of SSM stems mainly from its geological past: SSM has been the destination of intense migration of plants and animals. According to(Toledo, 1982), Los Tuxtlas and SSM maintained relatively stable climate conditions during the abrupt climatic changes of the Pleistocene. It therefore represented a refuge for the tropical biota threatened by those changes. At present, Los Tuxtlas is regarded as the northernmost patch of tropical rain forest in the American continent(Dirzo & Garcia, 1992).

Table 4-6 provides some interesting comparative insights on the high concentration of species in a relatively small geographic area like Los Tuxtlas. For example, although Los Tuxtlas covers just 3% of the state of Veracruz, its jungles contain 55.8% of the different vertebrates known in the state (birds, mammals, reptiles, and amphibians). As for birds, 40% of the species reported in Mexico, 47% of those known in Costa Rica and 23.8% of those reported in Colombia can be found in Los Tuxtlas. The plant life in Santa Marta could account for up to 25% of the species reported in Veracruz and 7.6% of the species known in Mexico. On the basis of this information about the concentration of known and described species, it is fair to suppose that SSM may host additional ones which still remain undescribed.

Table 4-6: Comparison of the number of species in different biological groups in Los Tuxtlas with those found in the state of Veracruz, Mexico, Costa Rica and Colombia

Place (km2)	LOS TUXTLAS 2,500)		VERACRUZ (71,699)		MEXICO (1,975,000)		COSTA RICA (50,900)		COLOMBIA (1,138,338)	
BIOLOGICAL GROUP	No. spp.	%, Los Tuxtlas	No. spp.	%, Los Tuxtlas	No. spp	%, Los Tuxtlas	No. spp.	%, Los Tuxtlas	No spp.	%, Los Tuxtlas
MAMMALS	102[1]	100.0	164[6]	62.2	439[8]	23.2	201[12]	50.7	358[12]	28.5
BIRDS	405[2]	100.0	700[6]	57.8	1010[9]	40.0	850[12]	47.6	1700[12]	23.8
REPTILES	107[3]	100.0	211[7]	50.7	717[8]	14.7	199[12]	53.2	375[12]	28.2
AMPHIBIANS	44[3]	100.0	85[7]	51.7	284[8]	15.1	150[12]	28.6	362[12]	11.8
BUTTERFLIES	359[4]	100.0	600[6]	59.8	2,500[10]	14.3	1,200[12]	29.9	4,500[12]	7.9
VASCULAR PLANTS	2,000[5]	100.0	8,000[8]	25.0	26,071[10]	7.6	12,119[12]	16.5	51,220[12]	3.9

[1] González-Chistensen, A. y E. Rodríguez-Luna. 1986 Los mamíferos tropicales de la Sierra de Santa Marta, Veracruz. IV Simposio sobre fauna silvestre. Memoria UNAM y Asoc. de Zoológicos y Acuarios de la República Mexicana. pp 24-35

[2] Winker, K., R.J. Oehlenschlager, M.A. Ramos, R.M. Zink, J.H. Rappole, & D.W. Warner. 1992. Avian distribution and abundance records for the Sierra de Los Tuxtlas, Veracruz, Mexico. Wilson Bull. 104 (4): 699-718.

[3] Morales-Mávil, J. 1995 (Personal communication).

[4] Ross, G.N. 1967. A distributional study of the Butterflies of the Sierra de Tuxtla in Veracruz, Mexico. Ph. Dissertation Lousiana State University and Agricultural and Mechanical College. 226 p.

[5] Ramírez, R.F. 1993. Biodiversidad y estado de conservación de la Reserva Especial de la Biósfera "Sierra de Santa Marta". En Memoria de resúmenes del Primer Congreso sobre Parques Nacionales y Areas Naturales Protegidas de México: pasado, presente y futuro. Universidad Autónoma de Tlaxcala. (pp. 305-307).

[6] Flores- Villela y P. Gerez F. 1989. Patrimonio Vivo de México. Conservation International, New York.

[7] Pelcastre y Flores-Villela, 1993.

[8] Flores-Villela, O. y P. Flores F. 1988. Conservación en México: Síntesis sobre vertebrados terrestres, vegetación y uso del suelo. INIREB Conservación Internacional, 302 pp.

[9] M. Ramos O. (Personal communication).

[10] Williams-Linera, y G. Halffter y E. Ezcurra. 1992. El estado de la biodiversidad en México. En: G. Haffter. (Comp.) la Diversidad Biológica de Iberoamérica Acta Zoológica Mexicana, Vol. especial pp. 285-312.

[11] World Resources Institute, 1994. A guide to the Global Environment. People and the Environment. Oxford University Preps. pp 315-330.

[12] Valerio, E. C., 1991. La biodiversidad de Costa Rica, Editorial Heliconia, Fundación Neotrópica San José, Costa Rica. p. 13.

The agrobiodiversity of the SSM is also important. There is anecdotal evidence of a large range of varieties of maize and beans that have been selected and maintained by indigenous people in the past. Many of these traditional varieties are now disappearing because of marketing constraints, or changes in the dietary habits of local communities. An integrated strategy of biodiversity conservation for SSM should also include the protection of landraces and traditional varieties.

On account of its unique geological and biogeographical background, the richness and degree of endemism of its flora and fauna, and its role of repository of the biodiversity of the Latin American region, Los Tuxtlas and SSM deserve particular attention in terms of activities for biodiversity conservation. Chapter 6 of the dissertation will discuss some of the main options for a conservation strategy, as well as their assumptions and management implications.

4.3. *The socio-economic environment*

The final part of this chapter presents and discusses information on the resident population's economic activities that directly or indirectly affect management of natural resources in the study area. Before proceed to the data, a simple conceptual framework will be proposed. This will help organize and systematize the information, and introduce some of the themes that will be developed and elaborated upon in the modeling exercises of the following chapter. The framework follows conventional extensions of neoclassical microeconomic theory to households which are both consumption *and* production units (see for example (Michael & Becker, 1973; Ellis, 1988).

Households have access to an endowment of factors of production: their total labor time ***T***, capital goods, and the land area that they own, borrow, rent or use with the community's tacit or explicit consent (see section 4.3.2 below for details on formal and informal land tenure arrangements). Accessible area can be broken down into basic land use categories: cropland, pasture, primary or second growth forest.

It is assumed that household derive utility from use of final consumption goods, defined ***Z***-goods: u=u(z). These are produced or transformed in the household using as inputs time ***T***, natural goods and services, ***N***, domesticated natural goods (e.g. agricultural crop plants and livestock) ***D***, and man-made goods, ***M***. A production function ***f*** specifies the technological possibilities for producing Z-goods: $Z = f(N, D, M, T_z)$

In-household production/ rearing of domesticated plant and animals is described by a function ***g*** of land area ***A***, labor time T_D, capital ***K***, and natural raw inputs: $D = g(N, A, K, T_D)$. The difference between own production and use of the various goods can be positive, in which case the superavit is sold on the market; or it can be negative, in which case the deficit is purchased in the market. On top of technology, households are subject to a time constraint: $T = T_w + T_D + T_Z$, (where T_w is employment off-farm at wage rate ***w***), and a budget constraint:

$$I + p_m M = p_D D^{Net} + p_N N^{Net} + wT_w$$

where I is income from other sources, the p variables are price vectors and the *Net* superscripts indicate the difference between consumption and use of the different types of goods.

Based on this broad framework, the rest of the chapter is organized as follows. In sections 4.3.1 to 4.3.3 the human capital and land endowments of the study area will be discussed; section 4.3.4 presents information on the activities that impinge on natural resources for the production/collection of domesticated/wild plant and animals; finally, section 4.3.5 discusses the evidence on non-farm employment and off-site sources of income.

4.3.1. Population

According to official census data, in 1995 in the study area lived a total of 57,804 people, distributed in 72 land tenure units (ejidos, ranching colonies, agrarian communities and private properties), belonging to four municipalities (Catemaco, Mecayapan, Pajapan and Soteapan). Between 1990 and 1995 an average demographic growth rate of 5.3% was recorded, which is more than twice the national rate (2.5%).

The population is composed for the most part of indigenous people (80%) of the ethnic groups "nahua" and "zoque-popoluca". The rest corresponds to "mestizo" populations of different origins. Indigenous people are especially concentrated in the southern portion of the study zone, with the nahuas located toward the southeast, in the municipalities of Pajapan and of Mecayapan, and the popolucas toward the southwest, in the municipality of Soteapan. The mestizos populated initially areas belonging to the Catemaco municipality (to the north-west of the SSM), and from there they have been expanding toward areas in Mecayapan and Soteapan. In some ejidos mestizos and indigenous people interact in daily life and share commercial and productive activities, but strong cultural differences persist, most notably with respect to natural resources management. In particular, indigenous communities are typically more inclined towards traditional, integrated management options of natural resource, based on sustainable systems of shifting cultivation. In contrast, in mestizos communities a mentality of natural resource "mining" prevails, such that large tracts of forests have been cleared for the sake of (often short term) gains associated with land extensive livestock activities.

4.3.2. Land tenure

4.3.2.1. Background on Mexico's land tenure system

Before discussing the data pertaining to the study area, a few words of clarifications on the general aspects of Mexico's land tenure system may be helpful[7]. Basic categories and parameters of land rights were defined in Article 27 of the 1917 Constitution, allowing three types of property: ejidos, small property, and communal property (comunidades). Ejidos constitute a land grant for usufruct to a population group, and until a major constitutional reform in 1992, ejido land essentially belonged to the state and could not be sold. Small property is privately owned and is subject to size limits according to the quality of the land and type of crop or economic activity. Communal property is based on the historical rights of pre-Hispanic indigenous communities who have maintained their traditional communal property structure.

Land was not distributed to ejidos immediately after the 1917 Constitution and only began to proceed in 1930. In subsequent years land distribution would vary considerably between presidential periods. When first distributed in the 1940s, all ejido land was communal, but many ejidos have since opted to parcel part or all of their land to individual "ejidatarios" (community members). Thus, some ejidos have communal land only (about 7 % of total ejidos in 1991), some have communal and parceled land (65 %), and some are completely parceled (28 %) (World Bank, 1994).

In 1992, in preparation for Mexico's joining in the North American Free Trade Agreement (NAFTA), major reforms of Constitution's article 27 and of the agrarian law were undertaken. The purpose was allowing the allocation of land among competing uses to become more responsive to international market forces. Under the new system, community

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[7] This section draws, among other sources, on material discussed in reports of the World Bank (World Bank, 1994; World Bank, 1995).

members are allowed to gain title over land. Subject to some limitations spelled out in the new agrarian law, ejidatarios are permitted to sell and rent their land, pledge it as collateral and form association with private investors.

In the intentions of its promoters, the reform will increase allocative efficiency in the agriculture, livestock and forestry sectors. Improved land property rights will result in more active land markets, which in turn will facilitate the allocation of the different types of land to their most profitable use; in particular, it is expected that inefficient, land-extensive cultivation of basic staple crops like maize and wheat will be replaced, possibly with the support of financial injections of foreign investors, by crops with a clear climatic comparative advantage, like citric fruits and other tropical produce.

In order to implement the constitutional and legislative reform, a major nation wide land titling program has been launched in 1993: the PROCEDE (*Programa de Certificación de Derechos Ejidales y Titulación de Solares Urbanos*, i.e. Program for Certification of Ejido Rights). PROCEDE is headed by the Minister for agrarian reform, with the National Institute for Statistics and Geography responsible for the preparation of maps and titles (World Bank, 1995). According to the World Bank, as of April 1995 only 20% of the ejidos included in PROCEDE's workplan obtained community level titles, and few individual private land titles had been granted. It is likely that because of the ambitious goals of the program, the poor quality of baseline information, the high costs involved, and the need to resolve a large number of infra- and inter-ejido disputes, PROCEDE will proceed at a fairly slow pace.

One of the key social issues that have been raised concerns the impact of the program on the different tenure arrangements (including formal and informal ones) that have been developing since the beginning of the post-revolution land distribution process. Both in private and communal land units, formal land rights holder ("propietarios" in the former case and "ejidatarios" or "comuneros" in the latter) are by no means the only type of land dwellers. Along with genuinely landless salaried agricultural laborers, there is a significant proportion of the rural population who does not possess neither private nor community land titles, and yet farms individual parcels of land by entering in contractual or informal arrangements (land rental, borrowing or sharecropping) with either private landlords or ejidos.

A broad term which describes this category of land users is "avencidados" (the other term sometimes used,"anexante", denotes titleless farmers whose parcel is in a community different from the one of residence). There are various reasons why a farmer may be an "avencidado". Because the title of "ejidatario" is inherited by only one of the incumbent's children, in several communities many avencidados are non-inheriting sons of land right holders; others are migrants from communities where opportunities for informal modes of access to land were limited. Even in the absence of contractual arrangements of a written or verbal nature, "avencidados" living in communal land units may also use common property land on the basis of the tacit or explicit consent of the ejido's authorities.

It is fair to expect that the overall social and economic impact of PROCEDE will depend on the way its implementation will affect the various situations of "de-facto" land use that can be encountered in rural Mexico. A strict application of the program, disregardful of informal tenure arrangements, may result in eviction of avencidados on a significant scale. This opens up a number of issues related to the social and economic costs of the likely resulting migration to urban areas, as well as questions about the capacity of some stagnant segments of the industry and services sector of absorbing the incremental supply of unskilled labor. From the environmental point of view, one reason for concern may be that, as a result of PROCEDE, evicted peasants unwilling or unable to migrate to urban areas may be forced to clear, for subsistence agriculture, marginal forested land, currently not subject to parceling processes under the agrarian law.

This may suggest some qualification to the conventional wisdom about the linkages between land tenure, deforestation and natural resource management in general. As it is often argued in the literature[8], lack of secure tenure is often a major cause of pressure on forests and other natural resources, so that titling program are often regarded as essential components of strategies for encouraging sustainable use of natural resources. At the same

[8] See for example(Pearce & Warford, 1993)

time, it needs to be recognized that improving the security of tenure of one part of the population at the expense of "de-facto" users may, in the absence of mitigation measures, have the undesirable effects of actually increasing pressure on forests[9].

4.3.2.2. Land tenure in SSM

Table 4-7 provides a summary of the different types of land ownership encountered in the study area. As it can be seen, communal arrangements (Ejidos and agrarian communities) are largely prevalent, amounting to over 70% of the area's size and to nearly 80% in terms of land tenure units.

Table 4-7: Types of land ownership (Source: PSSM, 1995)

Category	Type of ownership	Land Units	Size (has)
Communal	Agrarian community	2	11,280
Communal	Ejido	66	88,380
Comunal Total		68	99,660
Private	Private Agrarian Colony	6	17,984
Private	Private Property	12	14,952
Private Total		18	32,936
Other	Federal	1	152
Other	Irregular	1	3,064
Other Total		2	3,216
Grand Total		88	135,812

Area-wide-data on parceling, provided by the agrarian reform authorities, is available in PSSM's GIS , and is reported in the first three columns of Table 4-8. This data, however, does not allow to identify communities where partial parceling coexists with remaining communal spaces. More detailed information on parceling processes and on the availability of communal spaces was obtained through the key informant's survey. As illustrated by Table 4-8, out of the 41 communities surveyed, approximately two thirds have still communal land, either because the parceling process has not been completed (30% of the cases), or because it has not yet started (37% of the communities surveyed).

[9] This theme wil be the subject of quantitative analysis in the modeling exercise of subsequent chapters of the dissertation.

Table 4-8: Land parceling, various sources

	Area-wide data (Source: PSSM, 1995)			Key informants survey sample (Source: GEF and PSSM, 1995)			
Municipio	Land units	Un-parceled	Parceled	Land units	Incompletely parceled	Totally parceled	Commu-nal
Federal land	1	1		-	-	-	-
Catemaco	30	3	27	6	2	3	1
Mecayapan	25	6	19	13	5	6	2
Pajapan	3	1	2	1	0	1	0
Soteapan	29	17	12	21	5	4	12
Total	88	28	60	41	12	14	15

Excel file name: parcel.xls; Acees query names: "Types of ejidos"; "Parceling (region wide)"

In connection with the discussion of ongoing land reform programs (see section 4.3.2.1), it is of interest to map the different categories of land users in SSM according to the type of title of access to land they have. In particular, it would be desirable to determine the share of the population which has informal, precarious or no access at all to land. This would be the set of peasants who are most likely to be affected by the implementation of tenure reforms, and whose migration/ land use decisions may have a very significant impact on conservation of natural resources in the study area.

Table 4-9 provides a tentative taxonomy of the different types of dwellers in the SSM according to the type of land unit, to the availability of communal or otherwise encroachable spaces, and to the existence of a formal title of access to land.

A first indication about the extent of actual and potential (i.e. precarious tenure) landlessness comes from the way in which farmers interviewed in the individual household survey defined themselves . However, as is indicated by the shaded area of Table 4-9, the range of tenure arrangements that are covered by the terms "avencidados" or "anexantes" is a fairly large one. The table's taxonomy suggests that, even if "de jure" landless, "avencidados" do have "de facto" access to land in a number of ways. They may borrow land from relatives, rent it against cash payments or in return for provision of farm labor, or they may engage in share cropping arrangements. In communities where parceling processes have started, avencidado farmers may even have purchased individual plots. In this case, they will still not qualify as community land right holders (which excludes them from the community's various governance bodies), but they will have secure title on the purchased plot. In a few cases, avencidados are also present in private land units, like agrarian colonies or private properties. These may be farmers who have been excluded from land allocation during past processes of transition from social to private tenure; or they can be landless migrants from communal units.

Because of this broad range of possibilities, measuring the extent of actual and potential landlessness in the study area is not an easy task. The exercise is further complicated by the fact that farmers may feel nervous about answering questions on informal land tenure arrangements, in fear that the information provided may be reported to their disadvantage to the agrarian reform authorities[10].

Table 4-10 illustrates the range of different definition which can be used, and the quite different results which can be consequently obtained. Columns (5) to (8) report area-wide estimates obtained from the household survey. These are calculated by multiplying the number of households in each stratum times the proportion of landless farmers obtained through application of Equation 4-2 (see section 4.1.2.3).

[10] In the individual farmers survey, this factor affected in some cases the internal consistency of answers on the breakdown of individual holdings across the different tenure categories.

Table 4-9: taxonomy of land users (source: author's analysis)

		Access to land			No access to land
Type of land unit	**Encroachable spaces**	**Based on title**	**Not based on title**		
			Not based on any contract	Based on other contract	
Private	No: perfectly monitored private property	(1) Legitimate land owners	***(5) Peasants farming borrowed land***	***(9) Tenants, sharecroppers***	***Landless laborers***
	Yes (uncontrolled property)	(2) Legitimate land owners	***(6) Squatters, peasants farming borrowed land***	***(10) Tenants, sharecroppers***	
Social	No (parcelled communities)	(3) Ejidatarios, plus ***non-ejidatarios with purchased land***	***(7) Peasants farming borrowed land***	***(11) Tenants, sharecroppers***	
	Yes (unparcelled or partially parcelled communities)	(4) Ejidatarios, plus (where appropriate) ***non-ejidatarios with purchased land***	***(8) Peasants farming communal or borrowed land***	***(12) Tenants, sharecroppers***	

Legend:

The scope of the terms "avencidados" and "anexantes" is indicated ***by the bold italic font in shaded cells***

Column (5) refers to the percentage of interviewed farmers who defined themselves as "avencidado" or "anexante". It can be argued that this measure would unduly overestimate the extent of actual or potential landlessness, as many avencidados have in fact access to land, often in non-precarious ways (for instance when they buy a parcel of their own). Conversely, column (6), which adopts the most stringent criteria possible, i.e. counting in only farmers who have reported a size of zero for the parcel they have access to, is likely to underestimate landlessness (intended as factual but precarious access to land). The criterion of column (7) is somehow looser, as it includes farmers who have reported non zero holdings, and yet claimed to have neither access to communal land, nor to posses their own plot.

Column (8) include farmers who have just reported to have no privately owned land. The argument is that even if they have access to community land, this may be on the basis of a concession that the community has granted in the past, but can at any time revoke. This seems to be a plausible criterion, and has been adopted as a "best guess" estimate on the presence and distribution in the study area of actual and potential landless farmers.

Table 4-10: Landless population (actual and potential) by zone and municipio, various estimation criteria. Source: own calculations based on (GEF & PSSM, 1995) and (INEGI, 1997)

Zone	Municipio	Land units	Total Households	Sampled units	Sampled households	Stated "avecindados"	Totally landless	No ejido, no private land	**Best guess**: No private land	Forested land (has)	Landless/ 1,000 has forest	Pressure Index
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Buffer	Catemaco	4	159	4	56	18	0	0	7	3,739	1.91	0.00
	Mecayapan	6	201	6	36	27	10	16	27	1,352	19.70	0.13
	Soteapan	7	260	7	48	66	5	19	62	4,265	14.63	0.10
Buffer Total		17	620	17	140	111	15	35	96	9,356		
Influence	Catemaco	15	639	5	33	214	79	103	214	4,957	43.08	0.31
	Mecayapan	16	3649	8	110	607	14	312	600	10,081	59.56	0.43
	Pajapan	4	1525	2	30	168	0	84	168	2,274	73.68	0.54
	Soteapan	20	3604	15	218	1,639	54	391	1,412	10,472	134.79	1.00
Influence Total		55	9417	30	391	2,628	147	890	2,393	27,784		
Grand Total		72	10037	47	531	2,739	162	925	2,489	37,140		

{Reference: Access query "Landless area wide"; Excel table "Tenur1.xls"}

Finally, combining this information with the distribution of remaining forested land (column (9)), one can derive some preliminary indication about the spatial distribution of pressure on vegetation cover associated to potential land tenure conflicts. Column (10) measures the number of farmers with no private land per thousand hectares of forest. By normalizing this variable so as to make it vary between 0 and 1, one obtains the "pressure index" reported in column (11).

The index is based on the idea that the impact on vegetation cover will be higher where the per-ha-of-forest-density of actual or potential landless is higher. The preliminary indication provided by the index is that, all other things being equal, the highest pressure on conservation of the area's vegetation cover stemming out of changes in land tenure policies is likely to come from the influence-zone portion of the Soteapan municipality, followed by Mecayapan's influence zone. This consideration provides some of the input to the modeling exercises of the next chapter.

4.3.3. Land use

Information on broad categories of land use was obtained through consultation of PSSM's Geographic Information System. The results, summarized in Table 4-11, indicate that agricultural uses (which include croplands and pasture) predominate in the study area, amounting to about 60% for the entire region, with a range of 2% to 71% moving from the nucleus to the influence zone. Total land with significant vegetation cover (including undisturbed forest, second growth, degraded forests and forest fragments) accounts for about 36% of the study area.

Table 4-11: Land uses, zoning and municipios (Source: own calculations based on (PSSM, 1995)

Zone	Municipio	Land units	Area	Main forest	Other forest (a)	Agriculture (b)	Other uses (c)
			(hectares)				
Nucleus		1	152	132	-	20	-
Nucleus	Catemaco	1	3,064	3,028	-	36	-
Nucleus	Mecayapan	2	740	740	-	-	-
Nucleus	Soteapan	3	4,248	3,884	260	104	-
Nucleus Total		7	8,204	7,784	260	160	-
Buffer	Catemaco	7	7,724	4,228	724	2,736	36
Buffer	Mecayapan	7	6,004	3,012	324	2,604	64
Buffer	Soteapan	7	7,068	3,868	397	2,751	52
Buffer Total		21	20,796	11,108	1,446	8,090	152
Influence	Catemaco	22	16,664	1,456	3,482	10,854	144
Influence	Mecayapan	16	36,356	3,156	6,925	25,751	524
Influence	Pajapan	4	17,656	1,216	1,058	14,998	384
Influence	Soteapan	20	36,136	1,940	8,532	25,088	576
Influence Total		60	106,812	7,768	19,997	76,691	1,628
Grand Total		90	135,812	26,660	21,702	84,942	1,780

Access query name: Land use (aggregate2)

Notes:

(a): includes second growth, forest fragments and degraded forest

(b): Includes cropland and pasture

(c): mainly urban uses

4.3.4. Agriculture, livestock and forest use

The agriculture sector (including cultivation of annual and perennial crops, livestock, fishing and harvesting of animal and plants) is by far the most important in the study area, both in terms of allocation of households' labor and in terms of contribution to household income. Industrial activity within SSM is limited to two small hydro-electric and water treatment plant which generate a very small number of jobs. Trade in agriculture and other natural products takes place mostly through intermediaries, so that the number of residents whose primary economic activity is related to commerce is practically negligible.

4.3.4.1. Agriculture: cropping patterns

Table 4-12 provides area-wide estimates of how agricultural land is allocated to a selected number of uses, across different zoning/ administrative units (ZAUs). It is easy to see that pasture is by far the predominant use of agricultural spaces, accounting for over 65% of non-forested land. Maize, which is the second most significant use, is mostly cultivated for consumption within the farm household[11]. Among cash crops, chile and beans have some significance in a number of communities of the influence zone; coffee is also an important crop for the buffer zone, and for the communities of the influence zone with remaining forest cover (especially in the Soteapan municipality). Plantation of Chamedor Palm in second growth forest as an alternative to the more labor-intensive (and ecologically disruptive) practice of harvesting wild populations from the nucleus and buffer zone (see below, section 4.3.4.2.1) is a recent activity, and (as it can be seen from the table) still very limited in geographical scope.

[11] The average size of the area under maize ranges in the variuos ZAUs between 0.15 and 8 has, with 2 has as a reasonable area-wide average; with yields in the range of 1to 2.5 tons/ ha, harvests barely exceed the consumption needs of the average 4-6 individuals household with a diet mainly mased on corn.

Conversion of formerly forested land to pasture is a pervasive feature of land use patterns throughout SSM. However, farms in the region differ markedly in terms of the modalities of livestock activities undertaken.

With the help of data presented in Table 4-13, one can attempt some categorization. Around two thirds of resident households are estimated not to own cattle (they may still have land under pasture, which they can rent for grazing to neighboring cattle owners). Approximately one fourth of the household is estimated to possess small to medium size herds (that is, 1 to 5 heads, and 6-20 heads, respectively). Large herds above 20 heads are concentrated in the hands of less than 10% of the households.

Livestock is the most important source of agricultural income; as a result, it is plausible that a significant portion of cattle-less households are mainly subsistence-oriented. For small and perhaps medium size ranchers, livestock is likely to have mainly the purpose of providing a mean for investing family savings. For large rangers (and for some of the medium-size ones), ranching is a primarily commercial activity.

It is interesting to note that the Soteapan municipality features at the same time the highest cattlelessness rates and the lowest stocking rates (average number of cattle heads per hectare of pasture). This seems to suggest that in this part of the study area conversion to pasture has been at the same time highly inefficient and significantly inequitable.

Table 4-12 Cropping patterns, area-wide estimates (Sources: see notes to table)

Zone	Municipio	Land Units (a)	Area (has) (a)	Forested (has) (b)	Population (c)	House-holds (d)	Sampled units (e)	Size of sample (e)	Maize	Beans	Palm	Coffee	Chile	Other	Pasture Total (has) (g)	Pasture Average (has)
									Total (has) (f)							
Buffer	Catemaco	4	5,316	3,739	985	161	4	56	301	14	7	79	-	18	1,158	6.10
	Mecayapan	6	3,684	1,352	1,164	201	6	36	419	18	-	54	-	2	1,839	13.44
	Soteapan	7	7,068	4,265	1,251	260	7	48	502	51	20	167	4	0	2,058	7.63
Buffer Total		17	16,068	9,356	3,400	622	17	140	1,222	83	27	299	4	21	5,055	
Influence	Catemaco	15	15,244	4,957	3,589	670	5	33	1,301	324	-	74	43	88	8,457	13.67
	Mecayapan	16	36,356	10,081	22,433	3,677	8	110	9,502	1,568	-	1	317	81	14,807	13.74
	Pajapan	4	20,486	2,274	10,066	1,730	2	30	3,849	12	23	-	-	568	13,760	14.27
	Soteapan	20	37,636	10,472	19,485	3,632	15	218	6,132	913	77	2,398	71	47	17,526	8.23
Influence Total		55	109,722	27,784	55,573	9,709	30	391	20,784	2,817	100	2,473	430	784	54,550	
Grand Total		72	125,790	37,140	58,973	10,331	47	531	22,006	2,900	128	2,772	434	805	59,605	

Sources and notes:
(a): PSSM, 1995; (b) Own calculation based on PSSM, 1995; (c) Census data; (d) Own calculation based on survey information on average household size (GEF and PSSM, 1995); (e): GEF and PSSM, 1995; (f) Own calculation based on GEF and PSSM, 1995; (g) calculated as difference between non forested area and estimated total cropland

Table 4-13 Cattle ranching: size and distribution of herds

Zone	Municipio	Land units	Population total	House-holds in population	Sampled units	Sampled house-holds	Estimated Pasture (has) (a)	Total cattle	Stocking rate	House-holds with no cattle	Small herds (1 to 5 heads)	Medium herds (6 to 20 heads)	Large herds (over 20 heads)
Buffer	Catemaco	4	985	161	4	56	1,158	858	0.74	57.29%	10.62%	29.01%	3.08%
	Mecayapan	6	1,164	201	6	36	1,839	2,144	1.17	33.07%	27.62%	10.34%	28.97%
	Soteapan	7	1,251	260	7	48	2,058	309	0.15	76.04%	16.84%	7.12%	0.00%
Buffer Total		17	3,400	622	17	140	5,055	3,311	0.65				
Influence	Catemaco	15	3,589	670	5	33	8,457	10,042	1.19	43.88%	15.09%	17.14%	23.88%
	Mecayapan	16	22,433	3,677	8	110	14,807	26,462	1.79	73.62%	12.68%	5.55%	8.15%
	Pajapan	4	10,066	1,730	2	30	13,760	16,175	1.18	40.79%	28.24%	22.74%	8.23%
	Soteapan	20	19,485	3,632	15	218	17,526	8,703	0.50	77.21%	12.62%	6.33%	3.85%
Influence Total		55	55,573	9,709	30	391	54,550	61,381	1.13				
Grand Total		72	58,973	10,331	47	531	59,605	64,692	1.085				
										66.47%	15.78%	9.95%	7.79%

Notes:
(a) estimate taken from the cropping pattern table

4.3.4.2. Uses of forest-related resources

In several communities of the study area, forest resources are an important asset for resident households, both in terms of direct use, and of income generation through sale of harvested products. Forested areas are a source of timber and non-timber products, of fuelwood, and are the habitat for both game and live-trapped animals. In the following sub-sections, survey-based information will be discussed on those aspects.

4.3.4.2.1. Gathering of forest products

Several species of plants are collected for use in the preparation of drugs, as building material, textile fibers, or are sold for ornamental purposes. Gathering activities are not normally undertaken throughout the year, but only during a number of months in which climatic and other ecological conditions permit them. Many of the gatherers are concentrated in communities of the buffer and influence zones closer to areas with significant forest cover. For a sub-set of four plants with particular commercial importance, Table 4-14 provides area-wide estimates of the number of households engaged in gathering activities, the volume of extraction per annum, and of the value[12] (based on 1995 prices) of the harvest.

Apart from the case of Chocho (*Astrocarium Mexucanum*, an edible sprout) where gathering rates (i.e. percentage of households engaged in gathering) are estimated to exceed 30%, collection of several species is not so widespread in the entire area (with gathering rates ranging between 0.5 and 8%) and yet can be quite important for individual communities adjacent to forested areas with the necessary ecological and climatic conditions.

Collection of Chamedor Palm is one of the main channels of residents' interactions with the nucleus zone and with primary or second growth forested area of the buffer zone. For many households in the buffer zone with small or no cattle herds, Palm is also an important source

[12] Information on this last category is not complete.

of cash to support family incomes. At the same time, the lack of direct access to the end export market (both national and international) forces gatherers to resort to intermediaries, who pay low farm-gate prices. For gatherers to meet their cash objectives, harvest rates often exceed regeneration rates; increasing evidence points to the resulting dwindling of wild populations of several palm species. Plantation of palms outside the nucleus zone has therefore repeatedly been proposed as a conservation strategy with double benefits: on the one hand, reducing the pressure on wild populations, and on the other, creating incentives for conserving primary and second growth forest which could otherwise be converted to pasture or agriculture.

Table 4-14 Gathering on non-timber forest products (Source: own calculation based on GEF and PSSM, 1995)

					Palm			Chocho			Bejucos			Ixtle			Other plants	
Zone	Land units	House-holds	Sampled units	Sampled Hholds	Gatherers	Extraction/ annum	Value (1995 MexPes)	Gatherers	Extraction/ annum	Value (1995 MexPes)	Gatherers	Extraction/ annum	Value (1995 MexPes)	Gatherers	Extraction/ annum	Value (1995 MexPes)	Species	Gatherers
Buffer	17	622	17	140	42	15,051	37,627	231	1,135,912		28	2,045,040		17	1,090,800		11	93
Influence	55	9,709	30	391	209	37,851	94,627	2,895	3,567,187		246	275,532		72	1,122,000		12	797
Grand Total	72	10,331	47	531	251	52,901	132,253	3,125	4,703,098		274	2,320,572		89	2,212,800			890
						28,485												
Unit						Gruesa								Kg				
Price/ unit (1995 MexPes)						2.5								150				
Access query name RECOLL																		

4.3.4.2.2. Trapping of live animals

Trapping of live animals is also a significant activity in a small number of communities of the study area. Trapped animals, which include songbirds like Clarines, Tucans and Parrots, monkeys and rare insects, are sold as mascots or captive specimens in towns inside and outside the study area.

In many cases, this activity is conducted illegally as it infringes national regulations on endangered species protection. As a result, data provided by farmers interviewed, summarized by Table 4-15, is likely to underestimate of the actual dimension of live animals trapping. In any event, based on sample information on community reporting trapping activities, it is estimated that between 350 and 400 households may be engaged in those practices. Because of the sensitivity of the topic, more detailed information on trapping such as number and species of animals captured, albeit available, is often not consistent; therefore, calculations on the proceeds from the sale of the catch has not been included in the table.

Table 4-15 Trapping of live animals (Source: own calculation based on GEF, PSSM 1995)

								Indicative annual revenues from sale of trapped animals (range or average, 1995 MexPes)		
Zone	Land units	House-holds	Sampled units	Sampled house-holds	Units reporting trapping	Trappers in sample	Trappers in population (estimate)	Clarin	Tucan	Parrots
Buffer	17	622	17	140	5	9	57			
Influence	55	9,709	30	391	9	14	323			
Grand Total	72	10,331	47	531	14	23	380	60-4,000	3,000	1,200-24,000

Access queries "TRAPPING" "SOME TRAPPING"; sheet "Pivot" of file TRAPP.XLS

4.3.4.2.3.Hunting

Hunting in SSM is undertaken both for direct consumption and for re-sale to buyers outside the study area. The latter is increasing in importance in recent years due to higher demand for game meat from households and restaurants in urban areas adjacent the region. Main species hunted include birds (Faisán real, Faisán gritón, Chachalacas, Palomas, Codorinces, ducks), reptiles (iguanas), monkeys, varieties of wildboars (Tepezcuintle, Jabalí), deers (venado real, venado cola blanca), other mammals (armadilos, squirrels, serete, mazate, tejón, rabbits).

Table 4-16 Hunting, area wide estimates (*) (Source: own calculation based on GEF, PSSM 1995)

Zone	Tot Population	House-holds	Land units	Sampled units	Sampled units with hunting reported	Percentage of household hunting	Kills/ household / annum	Kills/ annum
Buffer	3,400	622	17	17	11	28.77%	12.00	2,147
Influence	55,573	9709	55	30	21	20.85% (a)	8.56	17,322
Grand Total	58,973	10331	72	47	32			19,470

Notes

* Preliminary data
(a) Sample average

Access query "HUNTING"; sheet "Pivot" of file HUNTING.XLS

On the basis of survey information, it is estimated (see Table 4-16) that the percentage of households undertaking some hunting activities varies between 20 and 30% in the various zones of the region. Between 8 and 12 kills per household per annum are estimated, amounting to an approximate 20,000 kills per annum for the entire region.

(Estimating the financial value of the harvest would necessitate a finer break down, over the different species, of the data on aggregate kills; this has not been attemptede here).

Anecdotal evidence from both the household and key informant surveys suggests that because of past and current high harvest rates populations of several of the hunted species are declining.

4.3.5. Off-site employment, non farm income and migration patterns

There is a close relationship between the SSM and the main cities of the south part of Veracruz state. The towns of Acayucan and Jaltipan are the main market for cash crops produced in the SSM, as well as for staple crops purchased by SSM's subsistence farmers unable to cover consumption needs with their own production. Perhaps even more importantly, SSM has been a significant provider of workforce to the industrial triangle of Coatzacoalcos, Minatitlán, and Cosoleacaque, one of the most important petrochemical zone in Veracruz and in fact in the whole of Mexico.

In the past, the income of many families of the Sierra used to depend on the level of economic activity of the oil district. For example, during the second half of the past decade, 44% of the salaried population of Pajapan were employed in the cities of the district: 29% in the construction and 15% in rural and urban services (Buckles, 1987).

Following a period in the 1980s of reduced activity of Veracruz's oil industry, measures of sectoral restructuring have been launched in the early 90's. These measures also include the proposed sale of a number of petrochemical complexes in the southern district. As a result of the crisis and the following restructuring packages, unemployment in southern Veracruz has increased alarmingly. In the Cosoleacaque - Minatitlán - Coatzacoalcos corridor, which used to be the single most important source of employment of southern Veracruz, more than 50 thousand jobs have been lost; the city of Coatzacoalcos features the highest unemployment rate (9.8%) in the domestic trade and services sectors.

Another outlet which traditionally provided temporary employment opportunities to the SSM, is given by the agricultural activities that require seasonal labor in neighboring localities. The Perla del Golfo colony receives annually, during the chile agricultural cycle (April - June), a significant number of workers from the SSM (approximately 400 laborers).

Seasonal employment to the Perla has traditionally been attractive due to the high wages paid: between 25 to 30 pesos per day, which compares well to the 10-15 pesos rate normally paid in the indigenous zones of Mecayapan, Soteapan and Pajapan. Another zone with some significant demand for farm labor is the zone of Chinameca and Tonalapa (neighboring localities of Mecayapan and Soteapan) during the papaya harvest between May and July. However, both of these temporary source of employment are at present insufficient to absorb the excess labor supply of the SSM. In the wake of the crisis, the flow of seasonal workers toward Perla del Golfo has decreased, since payment of the formerly high wage rates can no longer be guaranteed.

In the face of Veracruz and Mexico's economic downturn, many former migrants from the Sierra de Santa Marta have been forced to return to their localities of origin, thereby increasing population densities and putting more pressure on land and natural resources. (Blanco 1995). This is illustrated by the case of the Tatahuicapan community, where the number of "avecindados" rose from 900 to 1733 between 1991 and 1995, most likely due to the crisis-induced return migration from the oil district..

Table 4-17: Migration patterns and off-site employment, key informants survey (Source: own calculations based on GEF and PSSM 1995)

Zone	Municipio	Land units	In migrant families, 1990-95	Out migrant families, 1990-95	Permanent off-site workers
Buffer	Catemaco	3	73	41	25
Buffer	Mecayapan	6	12	39	6
Buffer	Soteapan	7	8	21	
Influence	Catemaco	3	10	5	3
Influence	Mecayapan	7	25	18	49
Influence	Pajapan	1	10		
Influence	Soteapan	14	45	43	22

Access query name: Migration and off site empl by zone

Table 4-17 summarizes information gathered in a subset of 41 communities, through the key informant survey, on net regional migration flows and current permanent employment outside the study area. Despite some cases of positive out-migration, the general trend during the period 1990-95 has been one of return to rural areas; the prospects of permanent employment outside SSM are not encouraging, as highlighted by the last column of the table.

Table 4-18 provides area-wide estimates on the pattern of temporary off-site employment in SSM, as well as estimates of non-agricultural incomes. Household size averaged between 4.8 and 10 people, with average labor force (individuals older than 10 years) ranging between 3.2 and 6.5 people. An average of at most one person with temporary off-site employment was recorded, with average employment time reaching one year just in one case (the Catemaco portion of the influence zone).

The estimated total number of people with some temporary off-site employment is around 4,000, corresponding to less than 10% of the estimated economically active population. However, in terms of time, the ability of the regional economy to absorb SSM's labor supply is even lower. Out of the total working time of the economically active population (EAP), a weighted average of less than 5% is used in temporary employment in the industry and services sectors of southern Veracruz's economy. It follows that over 95% of the EAP's working time is available for (sustainable or unsustainable) use of the region's natural resources.

The last four columns of Table 4-18 provide estimates of non-farm incomes obtained through salaried work or through other sources (mainly sale of artisanry item, handicrafts, etc.). Non-farm activities in the study area generate an estimated per capita income of only US$ 88 per annum (according to World Bank data, in 1994 per capita income in Mexico was around US$ 4,000).

The recovery of the regional economy is not likely to be immediate; to be sure, it is plausible that higher regional unemployment rates will result from the prospective privatization of the petrochemical conglomerate of the industrial corridor Cosoleacaque - Minatitlán - Coatzacoalcos. Considering also the current population growth rates, it is not difficult to suppose that the pressure on natural resources and land in the SSM will be yet greater than what has been observed in 1995.

Table 4-18: Off-site employment, and non farm income (Source: own calculations on GEF and PSSM, 1995)

Zone	Municipio	Land units	Sampled units	House-holds in population	Sampled house-holds	House-hold size	Family labor, individuals/ household (a)	Off-site workers (avg per house-hold)	Off-site workers (sum)	Months of work per annum	Family labor supplied off-site (%) (b)	Wage income/ house-hold (1995 US$ (c))	Other non farm income/ house-hold (1995 US$ (c))	Total non-farm Income / house-hold (1995 US$ (c))	Total non-farm Income per capita (d) (1995 US$ (c))
Buffer	Catemaco	4	4	161	56	6.13	4.00	0.85	137	7.87	10.68%	1,063	97	1,160	189
	Mecayapan	6	6	201	36	5.79	4.09	0.63	126	4.54	7.75%	567	133	700	121
	Soteapan	7	7	260	48	4.79	3.07	0.14	38	0.40	0.63%	72	53	125	26
Buffer Total		17	17	622	140				300						
Influence	Catemaco	15	5	670	33	4.15	2.89	1.08	722	12	21.57%	1,044	166	1,210	291
	Mecayapan	16	8	3,677	110	8.16	5.94	0.47	1,737	2.95	3.90%	475	56	532	65
	Pajapan	4	2	1,730	30	10.05	6.53	0.16	277	0.76	1.13%	271	147	417	41
	Soteapan	20	15	3,632	218	4.80	3.20	0.28	1,001	1.53	2.45%	223	51	275	57
Influence Total		55	30	9,709	391				3,737						
Grand Total		72	47	10,331	531		48,955		4,037						
Weighted average						5.96	4.07	0.43		3.21	4.93%	427	75	503	88

Notes:
(a): includes all family member older than 10 years
(b): given by months worked off-site divided by (12* family labor)
(c): Exch. Rate used: 1US$=6.3 MexPes
(d): equals total non-farm income per household divided by average household size

ıex 4-1: copy of the questionnaires used in the field work

ENCUESTA PARA PRODUCTOR

COSTOS INCREMENTALES PARA LA CONSERVACION DE LA BIODIVERSIDAD EN LA SIERRA DE SANTA MARTA. (PSSM) Julio ´95

Entrevistador ______________________________

Fecha ____________ Hora ________________

ıunidad ____________________ Ejido ____________________ Municipio ________________

ıNTECEDENTES

Nombre del entrevistado ______________________________ a.2. Sexo______________
Edad
Originario
Tiempo de estancia en el lugar______________________________

____

M3 Distancia del camino principal a su comunidad ________________ Km.

ːd es :a.6. Ejidatario ☐ a.7.Propietario ☐ a.8. Avecindado ☐

a.9.Anexante ☐

. HERENCIA

	Cónyuge	Hijo /a mayor	Hijo/a menor	Repartida cónyuge e hijos	Hijas Hijos	Otros
Varón						
Mujer						

AMILIA

¿Cuántas personas viven en su casa?

	Adultos (más de 18 años)	Jóvenes (10 - 18 años)	Niños / Niñas (menor de 10 años)
Hombres			
Mujeres			

ENENCIA DE LA TIERRA

¿ Cuantas hectáreas tiene? Núm.:________________

M3 ¿Tiene parcela propia? Tamaño :________________

ıdro C.1.1.

ɔ de tierra	No. de has.	Ejido	Privada
ias			
tadas			
adas			
ería			

¿De sus hectáreas, cuantas destina para :

c.3. Monte ____________c.4. Acahual_____________c.5. Pasto ________________

RODUCTOR NUEVO

M2 ¿Si es usted un nuevo productor, de quién recibió la parcela :

	Préstamo	Super. Ocup.	Super. Total / Prestador	Renta	Super. Ocup.	Super. Total / Arrendador
ıdres						
ırientes						

ændo la recibió? 1993 ☐ 1994 ☐

GRICULTURA TRADICIONAL

Nota : Considere el cultivo con mayor superficie.

ꓛULTIVOS Y FORRAJES

		ESPECIES CULTIVADAS						
ʼidades		maíz de temporal	maíz de tapachoal	frijol	palma			
ırficie	has							
	tareas							
de siembra								
ɔo	mes							
ısecha	año							
ɟe semilla ʼiedad,	criolla, mejorada							
limientos	kgrs/cargas							
	gruesas							
	Años cult. la misma parcela							
	Tiempo de descanso en años							
ıs más comunes								
ticida para combatir ıs								
izante químico usado								
izante orgánico usado								

ya no siembra frijol, por qué ya no lo hace?

ɹándo fue la última vez que lo sembró?

RUTICULTURA

Especie cultivada	Superficie cultivada/ No. de matas	Producción / ha., Unidades/árbol rejas/árbol

HORTALIZAS

Especie cultivada	Unidades/ciclo de cultivo	Veces que la siembra al año	Autoconsumo	Venta

OCUPACION DEL TERRENO

ando le fue asignado su parcela?

<table>
<tr><th colspan="2"></th><th>Monte No. Hectáreas</th><th>Acahual No. Hectáreas</th></tr>
<tr><td colspan="2">I ¿Cuanto había?</td><td></td><td></td></tr>
<tr><td colspan="2">I ¿Cuanto queda?</td><td></td><td></td></tr>
<tr><td rowspan="2">3
ła pensado
nbar?</td><td>Aumento pasto</td><td></td><td></td></tr>
<tr><td>Cultivos</td><td></td><td></td></tr>
</table>

¿Cuáles son los mejores árboles para cortar leña? Enumerar por orden de calidad los 4 mejores árboles para a.

________________ 2________________
________________ 4________________

¿Cuáles son los que usted corta con más frecuencia?

________________ 2________________
________________ 4________________

¿Cuántos árboles para leña hay en una tarea de acahual?

____

¿Cuántas cargas de leña se obtienen por árbol (grande, mediano, chico)

Leña de árbol	Carga / Árbol
grande (15 mtrs. de alto)	
mediano (10 mtrs. de alto por 20 - 30 de diámetro)	
pequeño (10 mtrs. de alto)	

¿Cuántas cargas se sacan de una tarea? ________________

¿En cuánto tiempo corta una carga de leña? ________________

¿Cuánto tiempo se tarda en llegar al lugar en donde corta la leña?

____

¿A qué distancia está el lugar donde corta la leña?

____

a leñadores sólamente

¿Cuántas cargas de leña vende por semana?________________

¿En cuánto vende una carga? $________________

¿En dónde vende la leña?

____

;ANADERIA

. ESPECIES GANADERAS

M3	ESP ECI ES						GANA DERA S				
ıcepto	Bovinos	Equinos	Mular	Asnal	Porcinos	Ovinos	Caprinos	Gallinas	Guajolotes	Conejos	Otros
ıtidad											

MANEJO

M3 Bovinos	Núm.	Precio / Kgr.	Precio / Bulto
Novillos			
Torete			
Vaca			

Distancia entre su casa y lugar de venta : _______________ Km.

¿Ordeña usted sus vacas? SI ☐ NO ☐

¿Cuántos litros de leche ordeña diariamente?__________ Lts.

o de venta por litro : N$ ________________A quién lo vende ______________________________

n dónde y/o a quién lo vende?_____________

¿Produce queso? SI ☐ NO ☐

¿Cuántos kilos diariamente? _____________Kgr.

¿En cuanto vende el kilogramo? N$_________________

¿Donde lo vende?________________________

a cuando paren sus vacas? _________________

ntas parieron el último año? _________________

ntas crías se murieron?__________________

OTREROS

¿Cuántas vacas tiene en una hectárea de pastizal? ______________

¿Cuántas hectáreas destina a pastizales?________________ Has.

Tipo de pastos	No. Has.

¿Cuántas hectáreas renta?______________ Has.

¿Cuánto cobra por cabeza? N$ ________________

¿Le rentan potreros? S☐ NO☐

¿Cuánto le cuesta por cabeza? N$________________

:APTURA (ANIMALES VIVOS PARA VENDER)

Nota : Dividir en especies menores, mayores y aves.

Especies		clarines	tucanes	monos	insectos		
No. salidas por mes	alta						
	baja						
No. piezas capturadas por salida							
Duración por salida en horas							
No. personas							
Meses de veda							
Precio de venta							
Temporada de captura (meses)							

:AZA

		Especies menores	Especies mayores	Aves
Especies				
No. salidas por mes	Temp. Alta			
	Temp. Baja			
No. piezas cazadas por salida				
Duración por salida en horas				
No. personas				
Meses de veda				
Precio de venta				
Meses de temporada de casa	Alta			
	Baja			

:SCA

ıde pesca? Río☐ Lago☐ Mar☐

species					
orma de captura					
ant. Obtenida / kgr.					
leses de veda					
utoconsumo					
recio de venta / Kgr.					
ías a la semana					

ICULTURA

ədica a la apicultura : SI☐ NO☐

ERCADO DE TRABAJO

tos miembros de la casa trabajan para ayudar en los gastos familiares : ________

	Fuera de la comunidad	Dentro de la comunidad	Lugar	Ocupación	Epoca	$/Día
luctor						
ɔsa						

	Artesanías	Tipo	Cantidad	Precio
Productor				
Esposa				
Hijo				
Hija				
Otro				

ROCAMPO

:ibió apoyo de PROCAMPO? SI ☐ No ☐

a recibir apoyo de Procampo que requisitos le piden?

____

____

	¿Cuántas has. sembró	¿Cuántas eran de monte?	Cuántas eran de acahual?	¿Cuánto levantó de cosecha por ha.?Kg/Cargas	¿Vende parte de su cosecha o es para autoconsumo?	¿En cuánto vende el kilo de maíz?	¿¿En dónde lo vende?	¿Directamente o hay intermediarios

ño próximo, le gustaría seguir participando en Procampo? Si ☐ No ☐

ı cuántas hectáreas? __________

ıbraría en el mismo lugar que en 94 y 95 o cambiaría?

o lugar ☐ Otro lugar ☐

ambiaría, sería en acahual ☐ o en monte ☐

5. The process of land use change: past trends and prospects for the future

5.1. Introduction

The overall purpose of this chapter is to analyse the past, the present and the future prospects of biodiversity conservation in the case study area of Mexico. More specifically, this chapter will summarise the social and economic factors that have been responsible in the recent past for processes likely to result in biodiversity loss (land use change, unsustainable agricultural practices, over-harvesting of wild fauna and flora). It will then identify processes which are likely to have significant impact on the state of the ecosystem in the short to medium run, and propose models to analyse those impacts.

5.2. The past: historical overview of the process of land use change in the study area

This section provides an historical analysis of the interaction between communities in the region and the environment, from the turn of the century to the 1990s. This information provides the background for the modelling exercise of section 5.4, which attempts to identify the economic processes likely to affect land use over the next decade.

5.2.1. First half of the century

The land use pattern that prevailed up to the mid-1950s was linked to a production system composed of three complementary activities: (a) agriculture (mainly staple crops), (b) hunting and gathering, and (c) small scale livestock (mainly hogs and poultry). In spatial terms, the system was based on tradition- and community-ruled access to four agro-ecological sub-systems: the primary forest (*monte*), the second growth - fallow land (*acahual*), the cropping area (*milpa*), and the farm orchard (*solar*). The main feature of that system was that none of the activities demanded exclusion of the others to operate[1].

Under the system, the main crops were maize and beans, but were grown in association with more than ten other tuberous, gramineous, and fruit crops. The jungles and forests were additional sources of food, aside from providing products for other uses, such as construction. Popoluca and Nahua peasants sold coffee, loaf sugar, alcohol, and hogs on the market. Hog farming was accompanied by maize production, needed for fattening and breeding the animals. Maize, in turn, formed part of a farming system (slash and burn) based on grasslands/second growth forest (*acahual*) and jungle.

5.2.2. Second half of the 20th century

The production system described above was dramatically altered by the adoption of extensive cattle ranching, which had been little practised until that time and in any case only for on-farm consumption or saving purposes. Extensive cattle farming moved into the primary forest and into areas used for farming and regeneration (*acahual*).[2] Two stages can be distinguished in the development of cattle farming. (A) The introduction of cattle, linked to the initial stages of communal land enclosures, but located in very specific areas and restricted to a small group of farmers, which was the case of the Tatahuicapan and Pajapan municipalities from 1950 to 1970. Land concentration led to serious political conflicts in the towns(Buckles, 1987); (Velázquez 1992) and undoubtedly caused a loosening of family ties since a number of family units had to abandon their places of birth. (B) The expansion of cattle ranching to a larger number of farmers and communities, due first to the inception on a larger scale of communal land parcelling, second to the conversion of virgin forest, and third to more readily available bank loans.

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[1] (Pare, 1993; Chevallier & Buckles, 1995).

[2]In places where maize is grown under the slash and burn system, fallow lands (*acahual*) form part of the system since the land must be allowed to rest after a certain number of years.

Additional pressure on the traditional productive system was put from the decade of the 50s onwards by waves of domestic migration, caused both by unresolved land tenure conflicts in other Mexican states and by official colonisation policies. Newly-arrived settlers began to cut down trees to establish their communities and clear fields for their crops. Many of them came from areas traditionally dedicated to cattle ranching, and so imported a livestock-oriented mentality, often with little concern for necessary adjustments to local ecological and marketing conditions. However deforestation was not devastating in the early days, since most of the new settlers did not have the means to expand ranching on a large scale.

5.2.3. The impact of government programs in the 1970s

Much as in several other developing countries, in the three or four decades following the mid of the century Mexico's economic policy was guided by a development model based on import substitution, stabilisation, and heavy government intervention in the basic sectors of the economy. Programs were launched in a number of areas with significant impacts on the management of the country's natural resources. As discussed below, the consequences on the present study area were profound.

5.2.3.1. Cattle ranching

The expansion of cattle ranching in the Mexican tropics[3] was massive during the decades of the 50s through the 80s. In the southern part of the state of Veracruz the number of heads grew from 206,000 in 1950 to about 2.3 million in 1986; the area under pasture increased from 430,000 to 1.1 million in the same period (Lazos, 1995)

Two public programs introduced in the mid-1970s marked a distinct new stage in the growth of cattle farming. The Livestock Trust for *ejidos* and the Comprehensive Rural

[3] On the impact of cattle ranching on deforestation in Mexico and Latin America in general, see (Toledo, 1992)

Development Program (PIDERboth provided subsidized credit for cattle raising[4]. As described in detail for the Pajapan community by(Chevallier & Buckles, 1995), an indispensable ingredient for the rapid growth of pasture was the process of enclosure of communal spaces and of concentration of large extension of land into the hands of relatively few politically influential mestizos ranchers.

As an interesting qualifications to the diagrammatic analysis of chapter 2 (section 2.3), the land conversion sequence started in many cases not with road building, but with the replacement of swidden agricultural production with pasture in communal spaces located in the fertile lowlands areas. The displaced milpa production would then move into forested area uphill for a few years, that is, until yield drops and/or new enclosures would determine additional conversion to pasture, so that food crop production would be displaced even further in the forest.

The impact of enclosures and credit policies became visible by the mid-1970s. The forested area shrank from 96,640 hectares in 1967 to 60,857 hectares in 1976, i.e. 35,788 hectares of forests and jungle were lost in nine years (Ramirez, 1984). A land use model that would be difficult to reverse was becoming consolidated. The process of substituion of agriculture and forested land with pasture expanded as wealthier farmers began converting land, not only through use of subsidized credit, but also by investing their own resources. Once the land was turned into pasture, a complex web of social and economic interactions revolving around cattle started to develop: farmers would purchase their own cattle, obtain animals under sharecropping agreements, lease their pastures (or their herds) to ranchers in their communities or in neighbouring ones (Buckles, 1987; Chevallier & Buckles, 1995).

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[4] The first was a failure in organisational terms (it offered no real advantages for the new ranchers) and in financial terms (the loans were not recovered) and started the process of parcelling out the land, first in Tatahuicapan (1975-1977), then in Pajapan (1981) and in Mecayapan (up to 1990).

5.2.3.2. Coffee growing

As it did in other coffee-growing parts of the country, in the 1970s the Instituto Mexicano del Café (INMECAFE) [Mexican Coffee Board] opened up coffee warehouses in the Sierra and provided credit and advisory services for the introduction of technological changes to boost productivity. Government support for coffee farming was maintained during the entire decade and almost all of the 1980s.

This support had socio-economic and ecological impacts of different kinds: (a) it promoted the cultivation of new varieties (*caturra mondonovo*) that were more productive but with higher fertilisers requirements; (b) it introduced the use of agro-chemicals that were later extended to corn; (c) in terms of matketing, it broke a regime of monopsony a (in previous years was a main buyer from Acayucan, who imposed coffee prices at will); (d) the expansion of coffee, fostered by favourable conditions on the international market decresed the area dedicated to staple crop farming, with negative impacts on maize - based systems;[5] (e) the expansion of coffee growing had a beneficial impact on forest conservation to the extent that shaded coffee variety were adopted[6].

[5]In particular, fallow decreased in duration or was eliminated altogether. To compensate, farmers began to use part of the fertilisers provided by INMECAFE for the coffee plantations on their *Milpa* areas.

[6] The large numbers of coffee varieties can be grouped in two main types: shaded and unshaded coffee. Shaded coffee refers to a management technique whereby coffee is grown under shade trees of species found in tropical forests; while unshaded coffee is grown in cleared-up areas. The first type is normally compatible with the conservation of an ecosystem that retains many edaphic, biological and ecological characteristics of natural ecosystems. The second type of management entails a much higher degree of natural habitats modifications and homogenisation. See (Nestel, 1995) for a discussion of the economics of coffee growing in Mexico, and of the ecological implications of different varieties.

5.2.3.3. Forestry activities

In the 1970s the Mexican government also intervened in the Sierra's forestry activities. Two episodes are of particular significance. The first concerns the use of non timber products. The parastatal agency PROQUIVEMEZ promoted the exploitation of non-wood products which were in high demand in the decade of the sexual revolution. Mullein (*barbasco*) a root used to manufacture contraceptives, was greatly sought after by the pharmaceutical industry, just at the time when the government expanded its role into agriculture and other productive sectors. A government-owned company was established to sell mullein and the plant was harvested so heavily that it had almost disappeared by the end of the decade. In some communities in the sierra, such as Benigno Mendoza, the residents recall that it was thanks to mullein that they survived during the 1970s, when the jungle on much of their communal land was cut down to establish pasture (Pare, 1993).

The second episode concerns logging activities. In 1988 logging permits (773 hectares) were issued for two *ejidos* in the municipality of Mecayapan to supply a sawmill in Tatahuicapan. A large forested area was destroyed by harvesting timber in areas not covered by the permits.

5.2.3.4. Conservation policies

On April 28, 1980, the federal government responded to the concerns of academic institutions and declared the Sierra de Santa Marta to be a "protected forest and wildlife refuge zone". However this act was not accompanied by measures to implement it. No campaign was promoted to inform the public that the area had been protected nor was any management plan prepared to regulate production activities inside the protected area.[7] Despite the decree and in the absence of adequate legislation, the forestry authorities

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[7]Misinterpretations of the objectives of the decree resulted, as an effect of the lack of adequate information. Local communities thought that the government would expropriate all forested areas, and decided to clear them faster, while the better organised ejidos went to court to oppose the protected area.

allowed the sawmill that had been established in Tatahuicapan in 1979 to continue operating. It formally became the property of several *ejidos* in 1982 and continued to operate until 1989.

5.2.4. Recent agricultural and land use policies

In line with the changes in the global political and economic climate prevailing after the early 80s, and prompted by a serious financial crisis in 1982, Mexico undertook a significant change in its macreconomic and development policies. A liberist model was chosen, of outward growth based on structural adjustment. Macroeconomic and monetary policies focused mainly on inflation control, higher interest rates to attract international capital, and cuts in public spending. One of the main objectives of these policies was to create the conditions permitting the integration of Mexico into the world market under the North American Free Trade Agreement with the United States and Canada, which will become effective at the end of 1993.

To pursue the objective of Mexico's integration in the global economy, a number of reforms of the productive sectors' legislation and policies were adopted, with significant repercussions on the incentive framework for the management of natural resources in the country in general and in the in Sierra de Santa Marta in particular. In what follows, some key policies will be briefly summarised in the areas of land tenure, agriculture, and livestock.

Land tenure

The salient features of the ongoing land tenure reform have already been described in chapter 4 of the dissertation, including the amendments to Article 27 of the Constitution and the introduction of a new agrarian law. As mentioned in that chapter the main objectives of the reform is to shift from a mainly communal system of rural land tenure to a system of individual property. The reform is implemented through the Ejidal Rights Certification and Urban Land Titling Program (PROCEDE), which is administered by a newly founded public agency, the Procuraduría Agraria [Office of the Agrarian Commissioner], which is responsible for issuing property titles.

It has been observed that in several communities of the study area, PROCEDE is being (or is likely to be) the cause of inter-community and inter-family conflict, particularly conflicts between rightful claimants to the land, children inheriting rightful claim, children not inheriting rightful claim, and persons not entitled to any claim (*avecinados*)[8]. The outcome fi these disputes may be to indice evicted farmers to encroach into communal forested areas, which according to Article 59 of the Agrarian Act itself, are not subject to parceling processes[9].

Agriculture

Much in contrast to the high degree of public interventionism in the previous decades, the main thrust of the new policies is to open up Mexican agriculture as much as possible to market forces, and let them determine the optimal output and input mix, including cropping patterns, selection of production technologies and allocation of labour between the urban and rural sectors. This is accompanied by welfare programs and income support measures aimed at reducing the farmers' costs of adjustment and transition to the new equilibrium (and mitigate in the process the possible political costs of policies otherwise highly unpopular).

Maize production

A number of programs have had an impact on corn farming in Sierra de Santa Marta in recent years: the Programa de Apoyo al Campo (PROCAMPO) [Rural Support Program],

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[8]Subject to the semantic qualifications discussed in chapter 4, *avecinados* have no possibility of becoming *ejidatarios* and do not own the land. They normally rent or borrow land from *ejidatarios* or work with relatives who possess land.

[9]Agrarian Act, Article 59: "By law, the allocation of parcels in forests or tropical jungles shall be void".

the corn fertiliser program (better known as "credito a la palabra"), land conservation programs involving the construction of living hedgerows and stone terraces, and the green manure program.

As part of the strategy to obtain admission into NAFTA, president Salinas' government had to change its farm subsidy policies, since the guaranteed prices for staples were higher than international prices. Mechanisms were established to compensate for the gradual lowering of corn prices and of subsidies for other staple crops (beans, wheat, rice, sorghum, soya, cotton, barley, sunflower and sesame) over the next 15 years. Unlike the earlier subsidy (guaranteed prices per ton), the new PROCAMPO subsidy mechanism, in its first stage, relates to area and not to production, and consists of providing direct support (in cash) to producers to compensate for their loss of income. It has had a very great impact in Sierra de Santa Marta in the last two years, both with regard to extension (9,065.35 hectares in the study area) and with regard to its role in reviving corn production, which in the past had been consistently unable to cover the region's needs.

Before PROCAMPO, Sierra de Santa Marta had faced a crisis in obtaining enough corn for on-farm consumption. However, the program also had a heavy impact on deforestation of woodlands and on secondary growth (*acahual*). Although the program was not officially intended to open up new farming areas, to obtain more income many producers cleared land to expand the area they habitually planted, which averaged a maximum of 1.5 to 2.5 hectares. The situation was compounded by the lack of supervision of the Ministry of Agriculture, owing to a shortage of personnel.

Among the initiatives to support farmers' income, the corn fertiliser program was established in 1988 to assist in marketing and production for on-farm consumption, under the responsibility of the Instituto Nacional Indigenista (INI) [National Indigenous People Institute]. The program works with a revolving line of credit (at no interest)[10] as part of the

[10]The program supports producers with technological packages of farm chemicals.

Regional Solidarity Funds.[11] This program supported 83 producers with a total of 125 hectares in the study area in the last two years.

There have been other much smaller programs designed to address shrinking corn yield in the Sierra. The soil conservation and green manures programs were introduced on a small scale by the PSSM[12] (1992-1993). In 1994 a larger program was carried out in conjunction with the Department of Agricultural and Forestry Development of the State of Veracruz (SEDAP) and CYMMIT[13], but the PSSM continued alone with the program in 1995[14]. The stone terraces program was promoted by SEDAP and implemented by the Shared Risk Trust (FIRCO). The green fertilisers and hedgerows programs[15] were carried out simultaneously with the stone terraces program[16] in the same region but with no co-ordination between the two.

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[11]The National Solidarity Program (PRONASOL) was established during the Salinas government (1988-1994) as the linchpin of the new social policy to combat extreme poverty. Its chief characteristic was that the projects were targeted to the production of goods for sale, thus providing income and making it possible to recover loans, with the surplus used to maintain a revolving fund to guarantee the continuity of the program.

[12] PSSM: Proyecto Sierra de Santa Marta, a local non-governmental organisation.

[13] CIMMYT: Centro Internacional para el Mejoramiento del Maiz y Trigo, an intermational reserch centre on Maize and Wheat in the CGIAR network.

[14] In the first two years of the program, the PSSM covered 38 communities and about 2,200 farmers. In 1994 SEDAP carried out a soil conservation program together with the PSSM in the Los Tuxtlas and Santa Marta region. Administrative problems with the timely delivery of financial resources and the quality of the foodstuffs provided under the program were such that the PSSM decided to return to its normal scale of work and SEDAP did not continue the program in the region.

[15]The shelterbelts consist of planting the legume *cocuite* (*Glyricidia sepium*) between the rows of corn to retain the soil by creating terraces.

[16]This technique consists of placing stones at intervals that are theoretically defined based on the grade and contour planting.

In short, the technological programs to support corn production have gone off in two different directions. The "credito a la palabra" is based on a technological package of farm chemicals, whereas the hedgerows, green manures and stone terraces program foster soil conservation and improvement with a minimum of external inputs. This second group of programs promote a land-intensive, soil conservation oriented approach to yield and income support which is also in contrast with the subsidy policy (PROCAMPO) which, if not properly monitored, favours an increase in production based on an increase in area.

Coffee production

The coffee groves are distributed in a very complex association with other crops and forested land. In some cases it is difficult to detect the transition between the coffee fields and jungle or secondary vegetation (*acahual*). Coffee is also grown in vegetable gardens (*solares*) on the outskirts of urban areas. The lower and upper limits of altitude are 300-400 to 1,000-1,100 meters above sea level.

In the study area there have been fewer fires in the coffee-growing zone than in the livestock or corn-growing area, since farmers are interested in protecting the coffee crop because of its commercial value. Planting of other crops in the coffee fields has contributed to the conservation of biodiversity, with regard to both plants and animals.

As described in section 5.2.3.2, much of the development of coffee growing activities in the study area and in other parts of Mexico was linked to support provided to small holders by public agencies, in terms of technical assistance, extension, marketing and price buffering.

The major withdrawal of the government from many of the previous forms of support to the coffee sector, coupled with a sharp drop in international coffee prices at the end of the 80s changed dramatically the condition of production for many Mexican coffee growers[17].

[17] There is field evidence that in the early 90s, as a result of the crisis, many coffee groves were either abandoned or converted to other uses.

In the study area, the closure of the INMECAFE office in Acayucan when the institution was dissolved[18] strongly affected the coffee growers of the region. Advances against crops, coffee improvement programs, rust control programs, and all the technical advisory services that had extended to over 80% of the coffee-growing zone ceased. Since 1989, government assistance has been limited to specific aid for coffee zones that suffered heavy frost damage and to the transfer of the processing plants to producers. In 1991, responsibility for support for coffee growers with less than 2 hectares was transferred to the INI (National Indigenous People Institute), which became the administrator of the Regional Solidarity Funds. As of 1995, the coffee program currently provides support for 866 producers with 1,341.5 hectares in the study area.

Cattle ranching

The massive expansion of cattle ranching in the second half of this century transformed profoundly the landscape of the study area. As it was illustrated in chapter 4, recent land use data suggest that pasture accounts for over 40% of the entire study area.

Much of the transformation process was determined by a combination of credit policies, migration waves and social and political processes leading to enclosures and land concentration. As argued by scholars on the basis of extensive field evidence(Chevallier & Buckles, 1995), the conversion nearly always resulted in significant ecological damages, and rarely, if ever, in long lasting[19] financial returns to ranchers. In cases where the

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[18]As a result of the new policies of the Salinas government, INMECAFE's coffee processing installations were transferred to producers, with no prior training. The transfer led to serious difficulties since the farmers had never managed a warehouse or a processing plant.

[19] Under certain ecological and financial conditions, relatively high levels of short-lasted profitability may make financial sense from the point of view of the individual rancher. This will be the case if nutrients stored in the soil and vegetation of land turned into pasture can be mined quickly enough that the initial investment cost can be recouped and the end-of-period value of the herd can be reinvested elsewhere in the economy,

availability of communal land permitted it, ranching took place under land-extensive conditions, that is, with low stocking rates[20] (ratio between number of cattle heads and land under pasture). In cases where further extensive conversion were limited by geo-topogrphical or land tenure constraints, new pasture became more intensively grazed. However the more intensive land use was typically not followed by more intensive management, so that productivity, measured in terms of animals live weight, rapidly dropped.

Virtually all of the federal programs that provided strong financial incentives to ranchers have been discontinued, in the context of the broader policy of public disengagement from the agricultural sector. At the state level, there is some sign that policy makers have become aware in recent years of the ecological damage and economic inefficiency of the livestock policies of the past. Attempts to increase the land efficiency and productivity of cattle ranching have been made through the "intensification modules" of the Integrated Forest Development Program in Los Tuxtlas, funded by the State's government Secretary for Agriculture between 1990 and 1992; reforestation campaigns have been promoted repeatedly, albeit often haphazardly, to restore the soil and watershed protection function of the most severely degraded areas[21].

While deprived of the public support obtained in the past, livestock activities may be revitalised by the financial crisis of the end of 1994. The devaluation of the peso increased

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before overgrazing and poor management result in productivity decline. For a discussion of a similar process in the context of the Brazilian Amazon, see (Schneider, 1995).

[20] Evidence on low stocking rates in several ecological and administrative units of the Sierra was presented in chapter 4, on the basis of survey data.

[21] For example, the government of the State of Veracruz has promoted in the mid 90's a program of groundwater recharge and runoff control through the construction of "mini-catchment" tanks ("tinas ciegas") and subsequent reforestation, to be applied to the higher slopes of the San Martin Pajapan volcano (which is located in the nucleus zone of the study area). The original plan was to apply the scheme to 2,000 has. Due to budget constraints, the construction of the mini-catchments could be carried out only on 180 has

the potential competitiveness of the low-input dual purpose[22] livestock system typical of tropical areas like the Sierra, both in absolute terms (lower export price of output) and more importantly, relative to the more intensive, high-input, import-dependent systems of the temperate zones of Mexico. Of course, in terms of sales to the domestic markets, this potential may not be realised until the stagnation of domestic income and consumption caused by the devaluation will be reabsorbed, so that the demand for income-elastic goods like meat can be restored to pre-devaluation levels. Furthermore, a significant number of ranchers who benefited in the past from subsidised public credit are now heavily indebted and in some cases insolvent, so that only a smaller number of financially stable ranchers may be able to seize the post-devaluation opportunities.

Assuming that, even in spite of the above financial and demand-side and constraints, there may be a boost to tropical livestock production, two different effects on land-use pattern of are possible. On the one hand, the increased competitiveness may result in further expansions of the pasture frontier wherever land tenure, geographical and topographical conditions allow it. On the other hand, large extension of under-utilised and poorly managed pasture offer significant opportunities for intensifying livestock operations and concentrate them in smaller areas, with the ensuing possibility of increasing regeneration areas under fallow so as to improve buffering around remaining forest. The significance of this option in the context of a conservation strategy for the region will be discussed later.

[22] There are two main livestock farming models in the sierra: dual-purpose (that is, diary and beef products) and fattening, beef-only. Dual-purpose farming is widely found in the north, northwest, west, and central parts of the sierra, with beef-only mainly located in the south, in the old Indian towns of Pajapan, Tatahuicapan, Mecayapan, and Soteapan, and in some nearby ejidos.

5.3. *The present*

The previous sections of this chapter have reviewed the evolution of the policy context and of key social and economic processes in the study area over the last five decades. One key conclusion is that the region's traditional system of production and interaction with the ecosystem, by and large a legacy of pre-Hispanic times, has been profoundly altered in the second half of this century. The present situation retains few of the characteristics of the earlier system, in terms of appearance of the landscape, land use patterns, social organisation, cultural and religious customs (Chevallier & Buckles, 1995). The key determinants of the process of transformation have been identified in changes of the regional, national and international economic climate, policy interventions, shifts in the control of land and other natural resources among social and ethnic groups.

Which of the "old" causes of change are still likely to play a role, and which new ones are likely to emerge? This is the question addressed in qualitative terms in this section, and in quantitative terms in section 5.4 and subsections.

5.3.1. The legacy of the past

At the time the field work of the present research was undertaken, the Sierra appeared as a fairly impoverished region, both from the ecological and socio-economic point of view. Forest, at the mid of this century the dominant form of land cover, was restricted to barely a third of the study area. This entails a greatly reduced habitat size for many of the species that make up the biological richness of the region, and in several cases it may eventually entail risk of extinction[23], unless adequate measures are undertaken to ensure conservation of remaining forests, and improve the buffering function lands surrounding them.

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[23] The literature on the critical size of ecosystem and on minimum viable population is extensive: see for example (Soulé, 1987; Shafer, 1990; Burgess & Sharpe, 1981; Harrys & Silva-Lopez, 1992). (Rodriguez Luna, Cortés Ortiz et al., 1995) and (Silva-Lopez, 1987) discuss minimum viable populations for selected monkey species in Los Tuxtlas, the broader region to which the present study area belongs.

From the social and economic point of view, a population that is growing at about twice the national rate is among Mexico's poorest. The lack of access to basic services like water, sanitation, electricity is particularly severe in the Sierra[24]. Agriculture in several communities provides the bare means of subsistence, with cash crops income limited by severe marketing and technological constraints and cattle-related wealth concentrated in the hands of relatively few ranchers. Opportunities for employment and income outside the rural sector have been declining with the crisis and pending restructuring of the Gulf of Mexico oil districts. As illustrated by the data of chapter 4, non farm yeraly income amount to about \$80 per capita on average[25].

5.3.2. The policy context

As many of the marginal areas of rural Mexico, the Sierra de Santa Marta has received limited benefits from the interventionist policies of the past, and is experiencing high costs of adjustment to the new, more limited role played by federal and state governments in the productive sectors. To be sure, the process of transition to the new policy stance in the agriculture and social sectors is far from complete, so that the ultimate impact on areas like the Sierra will depend upon the modalities under which the reforms of land tenure, income and welfare support and agricultural pricing will be implemented.

In the case of land tenure, chapter 4 discussed the significance presence in the region of farmers with unsecure access to land or none at all. These farmers also happen to be those who rely most heavily on the forest and other natural resources as a source of goods and services for direct use or for resale. The PROCEDE program is likely to improve the tenure security of farmers with rightful claims to land. However, its impact on de jure landless

[24] Application of the UNESCO methodology for the estimation of the degree of marginalization suggest that nearly 80% of the communities are to be found in the last (i.e., the worst) two deciles of the distribution of access to the above services(Cervigni & Ramirez, 1996).

[25] Nation-wide per capita income for Mexico was US\$3,320 for 1995.

farmers is not uncontroversial, and, as discussed earlier, suggestions have been made that it can even lead to more pressure on natural resource use.

It is unclear the extent to which a more developed land market (one of the ultimate goals of programs like PROCEDE) can meet the demand for subsistence means of the region's poorest farmers. It is likely that in the short run many of them will have neither resources of their own nor adequate access to credit to purchase formal land rights. It is also likely that only a significant boost of the regional economy can generate employment opportunities for the evicted farmers, either via migration to the urban sector or through salaried work in rural areas.

Given the growing integration of Mexico into the global economy, the revitalisation of the economic activity in both the rural and urban sectors is clearly dependent upon general trends in the international economy, upon which national policy makers have little or no influence. However, public policies may have a role to play in choosing measures to mitigate the social and economic impacts of local adjustments to new equilibria in the national and international markets. This need not be, as in the past, in the form of direct income support, nor of distortion of market prices. For example, technical, institutional and capacity barriers can be removed, which prevent access of small holders to markets for natural products, for which marginal tropical areas may have an agro-climatic and image-marketing comparative advantage. These issues will be discussed again in the next chapter.

5.3.3. Driving forces for change in the present with a likely impact in the future

The rest of this chapter will provide an analytical framework to estimate in the short to medium run the impact of economic activities onto biodiversity conservation in the region. This exercise is challenging for a number of reasons. First, there is the complex issue of choosing a biodiversity objective function. What is the biodiversity that is to be protected, and correspondingly, what are the process of loss that have to be analysed? Is the objective to conserve the remaining primary forests, or also other forms of vegetation cover (like second growth forest)? What types of land uses are to be considered a threat to biodiversity, and therefore included in the analysis of the process of loss?

The second problem concerns the choice of the "explanatory variables". In real life, the interaction of observable variables both within natural and socio-economic subsystems, and between them, can be of daunting complexity. In the interest of keeping the modelling effort within tractable dimensions, there is the need for singling out a few processes and corresponding parameters considered as key in determining the change. In the next section, the following assumptions will be made.

i) Objective function

It will be assumed that biodiversity conservation will be affected by a) Intensive extraction of plants and animals from natural or semi-natural areas (negative impact); b) conversion to agriculture uses and pasture of areas with significant vegetation cover (primary and second growth forest, shaded coffee groves) (negative impact); c) size of currently perturbed areas devoted to vegetation regeneration (positive impact).

ii) Social and economic processes investigated

The analysis will focus on two broad categories of farmers whose resource allocation decisions are likely to have an impact on the biodiversity objectives identified above:

a) "New" sources of pressure: newly formed households and evicted farmers;

b) "Existing" sources of pressure: land use and land management decisions made by already established farmers

Predicting future impacts of human activities on the study area's biological resources entails i) an understanding of the forces that historically have driven the process, ii) identifying old and new forces which are likely to drive the process in the future and iii) analytical tools which can establish quantitative relationships between driving forces and biodiversity impacts. Section 5.2 has addressed the first aspect, and section 5.3.3 the second one. On the third issue, let us briefly review the literature on the linkages between human activities and biodiversity conservation or loss.

5.3.4. The causes of biodiversity loss and land use change in the literature

According to the discussion of chapter 1, an ideal analysis of the human influences on biodiversity would contain the following elements: a) a statement of the biodiversity conservation objective; b) an identification and hyerarchization of human activities with an impact on those objectives; c) a stylised representation of the process relating human activities to changes in the biodiversity objective; d) a formulation of dose-response functions for policy purposes. In reality, because of formidable conceptual and information difficulties, such an ideal path has seldom been followed in much of the biodiversity literature reviewed for this research.

A branch of the literature, using the "production function approach"[26], focuses on the last step of the above sequence. That is, it estimates the impact on human welfare of exogenous changes in some key feature of natural systems. To be sure, the exogenous variables used are typically not measures of diversity change, but rather provisions of ecological services. Recalling chapter one's discussion of the main argument used for justifying concerns for biodiversity (lower diversity → lower provision of ecosystem functions → lower human welfare), this is equivalent to saying that only the final link of that chain of reasoning is being addressed.

Other studies implicitly or explicitly adopt as biodiversity objectives that of minimising the degree of perturbation of biological communities. They then proceed to list underlying or fundamental human-related factors responsible for perturbations. Those lists often include population growth, consumption patterns, global trade, inequitable entitlements to land and

[26] For a discussion of the application of the production function approach to wetlands' environmental services, see (Barbier, 1994).

other natural resources, market and policy failures in correctly valuing biological resources' benefits (McNeely, Gadgil et al., 1995; Barbier, Burgess, and Folke, 1994; Pearce & Moran, 1994).

While clearly important to call the attention of policy-makers at the national and international levels, such a clustering of "global" factors runs into a number of problems. The first is that the identification of the exact objective function which is being pursued becomes problematic. The second is that the logical and chronological sequence of events leading from underlying forces to biodiversity loss is also not clear. The third is that the policy and management implications at the national and local level are difficult to draw.

There are a number of attempts to embody into quantitative models definitions of objectives, hypothesis about hierarchies of factors leading to loss, and assumptions about the interplay of those forces. However, few authors (Machlis & Forester, 1996; Forester & Machlis, 1996)[27] have actually attempted to model explicitly the impact on biodiversity of human factors.

A large part of the literature has been focusing on deforestation, especially in the tropics, with the implicit or explicit assumption that changes in forest cover are a good proxy indicators for measuring impacts on biodiversity.

As reviewed in (Brown & Pearce, 1994), a great deal of the deforestation literature applies statistical techniques (mainly multiple regression) to measure the impact of several human factor on changes in forest cover, both over time and across different geographic locations. Most of the studies specify on plausible a priori assumptions functional relationships

[27] In this approach, several statistical techniques are applied to test correlations between biodiversity indicators and a host of variables measuring human activities deemed responsible for biodiversity change and loss. Unfortunately, when applied to large groups of countries, or even to individual but large countries, these type of models face significant problem in terms of initial specification of relationships among dependent and independent variables, and in terms of interpretation of the results.

between forest cover (and/or forest cover change) indicators, and variables measuring population growth, poverty, income growth, external indebtedness, structural adjustment and other factors.

In some cases, there are competing theories that econometric analysis is supposed to scrutinise. Income, for example, can in theory be expected to have either a positive correlation with deforestation (via increasing demand of goods that require land clearance for their production) or a negative one (if the demand for environmental quality grows with income)[28]. Once specified on theoretical grounds, the relationships between deforestation and explanatory variables are tested using fairly aggregated, national level data, with the objective of providing decision makers with indications about the policy interventions that would be most effective to mitigate deforestation.

Several of this type of econometric studies of deforestation analyse statistical correspondences between changes in forest cover and broad explanatory variables. The problem in inferring cause -effect links from the conclusion of these studies is that few if any of them have an explicit micro-economic foundation, i.e. one that traces land use change activities back to the motivations underlying the individual agent's (household, agricultural or logging company) decision making process. Also, the use of very aggregated data forces the analyst to coarse policy prescriptions on a small numbers of factors revealed as "significant" by the statistical analysis, and makes it difficult to detect interaction among the explanatory variables which may lead to significant qualifications to the initial policy statements.

[28] Population growth is normally believed to have unambiguous positive links with deforestation. However, as observed by (Meyer & Turner, 1992), quoted by (McNeely, Gadgil et al., 1995), the connection between population and land cover change become weaker at increasingly smaller spatial scales because of the importance of other variables that affect demand, or spatially deflect its impact. For example, technological improvements may be able to reduce the land intensity of agriculture expansions that would be propelled by demographic growth.

There are however examples of studies of deforestation with explicit micro-economic foundations. An ambitious research program is currently under way (results are not yet available) (Vosti & Witcover, 1996), which seeks to improve the understanding of the forces leading to deforestation at the agricultural frontier via a three pronged approach: micro (farm), meso (region), and macro (country). The micro approach consists of a multi-period optimisation model of archetypical farms in the western Brazilian Amazon.

Two studies have recently been undertaken on deforestation in Mexico. These are of particular interest here, as they emphasise the potential role on future deforestation of policies that are being address also in the present research (see chapter 6 for a more complete discussion).

(Deininger & Minten, 1996) use disaggregated, municipality-level data to estimate the demand for land to be deforested on the basis of an agricultural household-type model. They find that physio-geographic factors, poverty, and government policies have distinct effects on deforestation. On the last two variables, they also argue that the recently adopted, NAFTA-induced, package of trade liberalisation and elimination of government interventions in agriculture, may result in increasing poverty of marginal farmers, who may not be able to benefit in the short run from increased opportunities coming linked to more open export markets, and are therefore likely to put additional pressure on forest and natural resources in rural areas.

A similar conclusion is also reached by (Barbier & Burgess, 1996), who estimate the increase in agricultural area and livestock numbers (a plausible proxy for deforestation) as a function of a range of price, income and policy variables. Barbier and Burgess argue that ongoing removal of input and output subsidies in agriculture may, on the one hand reduce incentives for conversion, but, on the other hand, it may make poorer farmers worse off and induce them to migrate to the agricultural frontier. In order to mitigate pressure on forests the authors therefore suggest to complement the broader liberalisation policies with a program of investments in land improvement for existing cultivation on rainfed areas.

This brief review of the literature suggests that a) few studies explain biodiversity loss (e.g. extinction, in the case of species diversity); instead, loss is explained indirectly, as b) most studies examine the causes of processes (land use change, species over-exploitation) that are likely to affect biodiversity; c) many studies of land use change focus on deforestation, with little attention to forms of land use in between full development and full conservation; d) few studies of deforestation have explicit micro-economic foundations, or use data at a disaggregated level.

With regard to these features, the contribution that this research intends to provide is based on the following elements:

a) Because there are many ways of defining it, biodiversity per se will not be the "dependent variable" in the modelling exercise; rather,

b) the behaviour over time will be projected, of selected indicators of ecosystem status (stock of different types of land, extraction of resources from the wild), which may be used for measuring changes in diversity according to a range of different objective functions;

c) Projections of land use and resource extraction are based on a microeconomic model of household behaviour;

d) Model projections are base on micro - data (at the farm and municipality levels).

5.4. *Prospects for the future: Modelling farm-level decisions*

5.4.1. Peasant farming and economic theory

The objective of the final part of this chapter and of the following one, is to model the interaction between the socio-economic and the ecological systems in the study area. To pursue that objective, the first step is to attempt to understand and capture analytically the behaviour and motivations of the main actors of the socio-economic system, that is the farm households. As illustrated in descriptive terms in the previous chapter, residents in the study area interact in a variety of ways with the eco-system. The first issue to address is what are the appropriate tools in microeconomic analysis which can explain those interactions.

It is often argued by scholars of various social sciences that a proper understanding of the behaviour of farmers living in marginal areas of the developing world, such as the present thesis' study area, require a distinct set of conceptual and analytical tools. In the social sciences, peasant and/or subsistence farming is the subject of a voluminous literature (Ellis, 1988; Dasgupta, 1993; Wharton, 1969; Clark & Haswell, 1970).

One fundamental issue under debate is the identification of the special feature that distinguishes the peasant household from other social and economic forms of rural organisation for production or consumption, and which therefore warrants the adoption of a special methodology of analysis. Various features have been highlighted as the main characterising element of the peasant household, including the primary orientation towards subsistence, the attitude towards risk, the degree of insulation from markets for labour, credit and insurance.

In economics, one of the key features that has been highlighted is the simultaneous decision making on consumption and production. The standard analysis of the economic behaviour of households with this characteristic is provided by the literature on agricultural household models (Singh, Squire, and Strauss, 1986; Barnum & Squire, 1979). A simplified account of the basic approach of these models, adapted to the issues addressed in the present context, can be provided in the following terms.

The farm household maximises a utility function which arguments are goods only available on the market, (***m***) and natural (***n***) goods[29], which can be either purchased or produced/gathered directly on-farm: u=u(m, n). Goods of the ***n*** type thus include both agricultural products and plants and animals harvested from the wild. The on-farm production of natural goods is *N*; for the time being, production of ***N*** is assumed to be a function of labour only: N=f(L).

The farm is subject to a time and budget constraint, which can be summarised as follows:

$$p_n(n-N)+p_m m = a + w(T-L)$$

where ***a*** is exogenous income or wealth endowment, ***T*** is total household working time, ***L*** is labour used in the production of on-farm goods *N*, ***w*** is the wage rate, and p_m and p_n are prices of market and on-farm produced goods, respectively. Depending on whether $T \underset{<}{\overset{>}{}} L$, the farm can be a net supplier or hirer of labour; and similarly, depending on whether $n \underset{<}{\overset{>}{}} N$, it can be a net buyer or seller of natural goods. In summary, the farm maximises utility through its choice of n, m and L subject to budget, time and technology constraints.

[29] This formulation of the farm's objective does not include two sets of goods that are often explicitly analysed by the agricultural household literature: leisure, and z goods, that is, goods that are produced and consumed on-farm only. The reason for the first exclusion is that it is assumed that in conditions of near subsistence, leisure time coincides with resting time, in turn determined on the basis of customs and of physical needs. Concerning z goods, detailed modelling of household conversion of ***m*** and ***n*** goods into final consumption goods is a very data-intensive exercise that the data collected for the present research can not adequately cater for.

First order condition for this problem are:

$$\frac{\partial u}{\partial m} - \lambda\, p_m = 0;$$
$$\frac{\partial u}{\partial n} - \lambda\, p_n = 0;$$
$$\lambda\left(p_n \frac{df}{dL} - w\right) = 0;$$
$$p_n(n - N) + p_m m = a + w(T - L)$$

(5-1)

The first three conditions are of course the standard utility and profit maximising conditions of conventional microeconomic theory, and the fourth condition reiterates the budget constraint.

One of the fundamental results of the agricultural household literature is the so-called independence of production from consumption decisions. Labour use and production are only determined by the profit maximising condition of (5-1; once the production decisions are taken, these determine the household's total income. Optimal consumption is then decided on the basis of the resulting budget constraint.

This point is illustrated in Figure 5-1. Optimal labour use L* is identified by the tangency between the production function and a line with slope w/p_n. This determines optimal production of N, which in turn, together with the initial endowment of household's time and exogenous income, fixes the position of the budget line in the space of consumption goods. For illustration, in Figure 5-1 the budget line is located at $budg^1$. Optimal consumption is then achieved by selecting the bundle (m*, n*). N*-n* happens to be positive in this example, and so has the interpretation of a marketed surplus of natural good production. Should it be negative, it would be a net purchase.

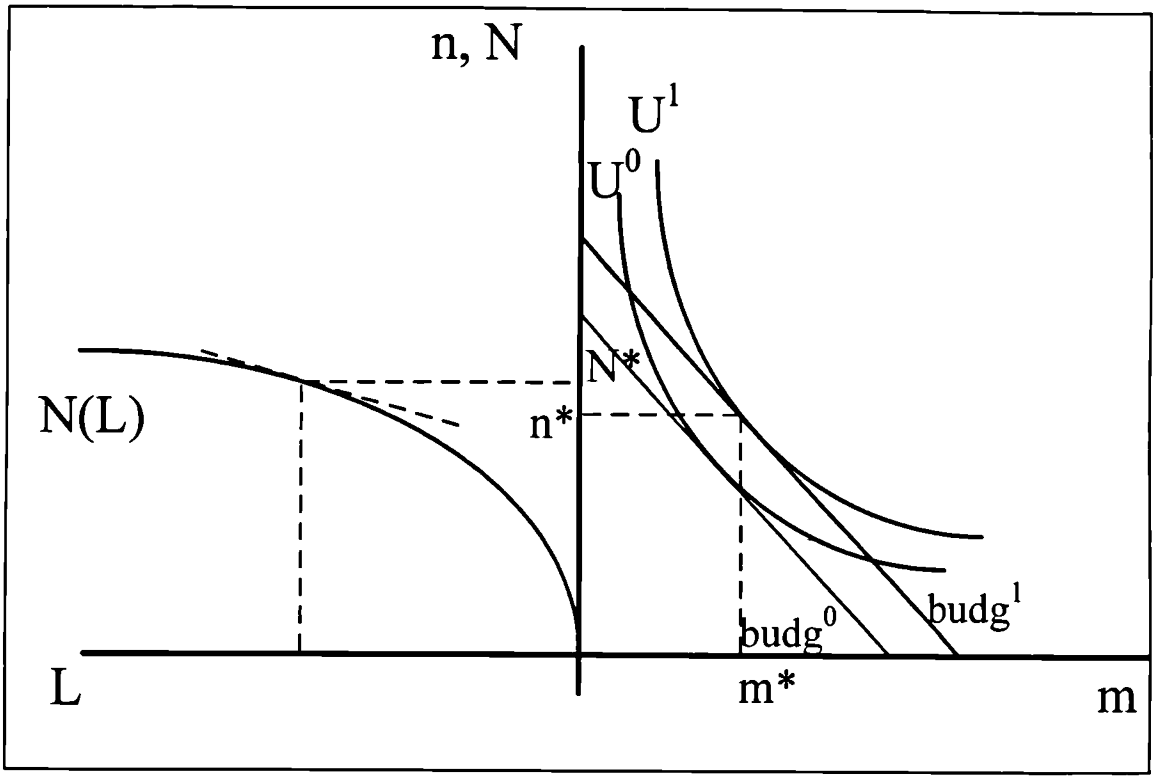

Figure 5-1 Equilibrium of the agricultural household

The critical element that ensures the separability of the production and consumption decisions is the existence of complete markets for labour and goods[30]. In general, the profit maximising level of production can be attained only if all the relevant inputs and outputs can be bought and sold as required, subject to economic and technology constraints only, and not to quantity constraints on hiring and selling which would prevail with imperfect access to markets. Under complete markets, utility maximisation follows income maximisation, which can be thus assumed as the main objective of the farm household. Farm's income is linear in output prices and quantities; this therefore justifies the use in the

[30] For analyses of cases where the decisions are interdependent, see (Nakajima, 1969; Ellis, 1988)

following sections of linear programming as an appropriate modelling techniques of farm behaviour[31].

Survival strategies

Some important qualifications need to be added to the assumption on (simple) income maximisation. There may well be cases in which (low) values of the initial endowments result in low values of the disposable income, which in turn result in very low levels of utility. In Figure 5-1, let us define U^0 as the minimum level of utility consistent with survival; all situations where the budget line falls short of *budg0* entail that the farm household puts its own survival in jeopardy. Survival may also be at stake when risk in introduced in the analysis. If the profit margin of *N* falls below the level expected at the time when production decisions are made, the budget line may fall, possibly below the minimum income level. In Figure 5-2 the effects of a drop in p_n are illustrated. There is an "expenditure" effect, whereby at the original level of income more of good n can be purchased; this translates graphically into a an upward shift of the budget line, in the direction indicated by *budg'*; however, the lower farmgate price of N reduces the farm's available income, pulling the budget line downwards; if the income effect dominates the expenditure effect, the net result will be a reduction in the available income, possibly below the survival level, as exemplified by *budg''*.

[31] Linear programming is also particularly suited to the analysis of decisions of the "some or none" type (Dorfman, Samuelson, and Solow, 1958), which are particularly pertinent in an agricultural household context (e.g. cropping patterns).

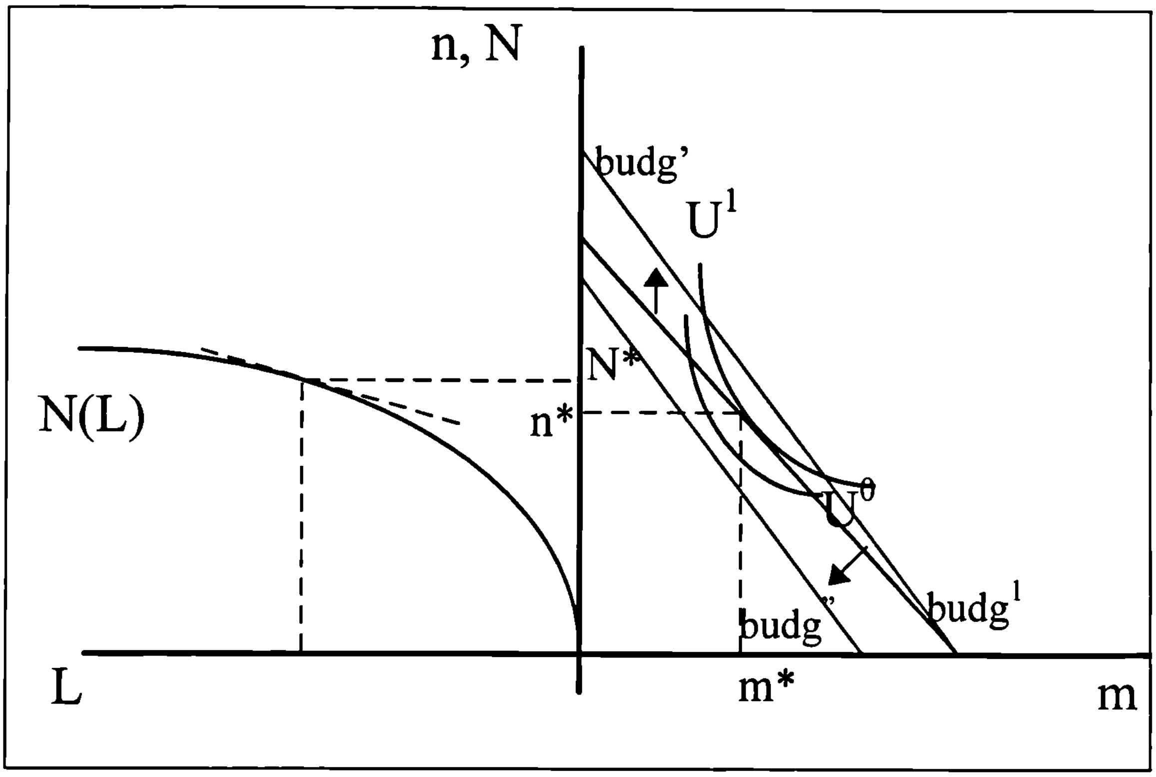

Figure 5-2 Agricultural household and survival objectives

What are the strategies that the farm household is likely to pursue to avoid survival-endangering situations? Two options will be considered and developed in the rest of the analysis. The first refers to the range of activities undertake by the farm household. There is a potentially large number of activities that the household can engage in to supplement income from food crops or livestock. For farms located in proximity of towns or other trading points these can consist of handy crafts production, small scale food processing (cheese, sweets) and so forth. In communities with more immediate access to forest and semi-wild areas, a broad range of natural products potentially may be extracted, which are valuable both for sale and direct consumption[32]. Regarding the second case, data on natural goods production and harvesting is unlikely to be exhaustive, be it in the present study area

[32] List and inventories of valuable forest and other natural products abound. For a recent thorough economic analysis of natural resources use in rural Zimbabwe, see (Cavendish, 1997).

or elsewhere. As a result, optimal production and consumption decisions resulting in level of income and utility below survival can be interpreted as *prima facie* evidence that additional, unrecorded production/ gathering of natural goods may be taking place. The analysis can then illustrate the magnitude of the profit margin parameters of the unrecorded natural goods, which would be necessary to guarantee achievement of minimum income levels (see below, section 5.4.2.6).

The second direction which can be pursued is to incorporate explicitly in the model risk related to profit margins. Of course, the literature on the appropriate treatment of risk in agriculture is vast (see for example (Roumasset, Boussard, and Singh, 1979) for a classical collection of papers). One standard approach is the expected utility framework: subject to a priori information on probability structures of uncertain events, farmers are assumed to maximise the expected value of a utility function which adequately represents their attitudes towards risk.

Quite apart from the substantial information requirement in terms of mean and dispersion of the variables identified as stochastic, it has been argued that the expected utility framework may not necessarily capture the behaviour of poor farmers who may be exposed to the risk of starvation and who may have very few resources to fall back on in case of disastrous outcomes. If there is a non-zero chance that survival is at stake, it might be little consolation to the farmer the fact such a chance is being minimised. The farmer may be more interested in strategies that allow for survival in worst-case scenarios, no matter how unlikely they are.

This is the justification behind some game theory-type models (McInerney, 1969), and safety-first approaches (Roy, 1952; Boussard & Petit, 1967; Low, 1974) that have been put forward in the literature. In what follows, an adaptation of Low's framework will be proposed. In Low's original model, the farm household maximises the expected total income subject to the constraint of satisfying a subsistence requirement under the most adverse state of nature. This represents a significant departure from the standard expected utility paradigm: the maximum expected income is likely to be larger than the maximum expected income subject to the survival requirement. Therefore, the farm gives up some of the maximum income attainable to provide against ruin. Formally, the farm's problem is:

$$\underset{N}{Max}\ \overline{p}_n N \ s.t.$$
$$p_n^h N + a = w(L - T) + S; \ h = 1,2,..., H$$

(5-2)

where $\overline{p}_n$ is a vector of expected margins for goods N, h is an index of the H states of nature identified by the farm, so that p_n^h is the price vector prevailing in the generic state of nature j, and S is the cost of the survival bundle of goods[33].

In the present analysis, Low's original model has been modified as follows:

a) Time horizon. Modelling farm households' impact on the ecosystem requires introducing in the analysis perennial crops and conversion of agriculture to pasture. The relevant time horizon for planning is therefore assumed to be 10 years. However, to make the model more manageable and decrease computation time, the linear programming tableaux actually used only go as far as three years. For most crops or activities considered, yields or returns stabilise after the third year. As a result, margins for year three incorporate the stream of benefits for years 3-10, discounted at the selected rate. That is to say, given original margins for year three c_3, the margin actually used in the tableau, $\hat{c}_3$, is given by the equation:

$$\hat{c}_3 = \sum_{k=3}^{10} \frac{c_k}{(1+r)^{k-3+1}} (1+r)$$

[33] For the sake of simplicity, the internal composition of the survival bundle has bee assumed fixed; in case of a change in the relative prices of the components, the farm is assumed not to substitute cheaper components for dearer ones.

where r is the discount rate. It is in fact easy to show (see Annex 5-1) that in general, the net present value of a series of T margins can be obtained by summing, up until a given cut-off year τ, the discounted values of the original margins, and for year τ, the discounted value of a "corrected" margin $\hat{c}_\tau$, which is the capitalised net present value of the margins from τ to T.

b) Objective function. One problem with the problem specification of (5-2) is that if S is large relative to the maximum attainable income, there may be no choice of N that satisfies the survival constraints. An alternative option is to express subsistence as a goal from which the farm household wishes to deviate as little as possible. The introduction of a multi-year time horizon requires that the farm tries each year to deviate as little as possible from its goal. This leads to a problem of multiple goal programming[34], whereby the farm minimises the weighted sum of deviations from set goals. The advantage of allowing for multiple goals is that income maximisation objectives can be introduced along with survival requirements. Various choices of weights are possible, reflecting different set of farm's priorities among the different objectives.

c) Subsistence requirements. When the analysis allows for multiple periods, there is a difference between the final income and the year to year cash-flow. Clearly the latter has direct bearing on the farm's subsistence prospects, as in every period the farm needs to have enough cash to purchase S. Therefore the single income requirement has been replaced by a yearly cash flow requirement.

d) States of nature. In principle, risk affects the entire set of element characterising the farm's decision making problem. Technical input coefficients and overall resource availability may be affected by adverse climatic and environmental conditions; profit

[34] On multiple goal programming, see (Hazell & Norton, 1986; Romero & Rehman, 1984; Bouzaher & Mendoza, 1987; Barnett, Blake et al., 1982)

margins may be affected by output prices fluctuations. To keep the problem within manageable dimensions, it is assumed that different states of nature are defined only by different values taken on by the prices of key outputs. In particular, it is assumed that these prices can take on, with equal probability, a "low" and a "high" value (these have been determined on the basis of unsystematic time series evidence from the field). If q is the number of output prices subject to random variation between a low and a high value, the total number of states of nature is $H=2^q$.

Sources of data

Information on crop margins, input coefficients and other parameters was obtained through field work undertaken in the summer - autumn of 1995 in context of the GEF - PSSM - CIMMYT study described in chapter 4. All prices originally denominated in Mexican Pesos are converted US$ dollars using the exchange rate of 6.3 MexPes per dollar, prevailing at data collection time. The analysis does not allow for inflation, so all prices and values are to be considered as expressed in constant 1995 US dollars.

5.4.2. Modelling newly formed farms' decisions

5.4.2.1. Purpose of the model

The model of this section attempts to describe the land use decisions of newly formed farms, with special emphasis given to farms located in areas with remaining communal land under primary or secondary forest cover. It is assumed that a new (subsistence) household is formed every time a male individual reaches the adult age, which on the basis of local customs, is considered to be 18 years. The farm household will require a certain amount of land for setting up basic staple crop (maize) production, plus possibly some additional cash crop or livestock activities[35]. The farm household may also allocate part of its labour resources to temporary off-farm employment, either working for other farms or undertaking non-rural jobs; finally, it may extract natural resources from the forest for sale or direct consumption.

The demand for land of the new subsistence farming households can be met in several different ways. Land can be inherited from parents and relatives, borrowed from friends and family, purchased, rented, farmed under share cropping arrangements. However, in communities with remaining unparceled land, use of communal spaces is often the first choice in terms of convenience and cost. It is assumed that the only communal land available for maize production is either under secondary or primary forest cover. The former is likely to be converted first because of lower access and conversion costs. Primary forest starts to be converted only when all second growth forest has already been converted.

In the present model it is assumed that where communal land is available, newly formed farms do not face a land constraint in their decision making. Rather than constraints, land conversion and uses are decision variables. Total land that will be converted to agricultural use is therefore the result of the various decisions taken by the farm with respect to land to be used for staple and cash crops production and for pasture. The newly formed farm faces labour, subsistence, cash flow and credit constraints. The essential features of the model are summarised in Table 5–1, and elaborated upon in the following sub-sections.

[35] Depending on the conditions of the local economy, members of households may decide to migrate to the urban sector to seek year-long employment in the oil district. This possibility will be included in the aggrgeate model of chapter 6.

Table 5–1: Features of the "new farms" model

	Objective	Decision Variables	Constraints
Household well-being	Minimise deviations from survival and prosperity goals		Subsistence consumption of maize and beans
Allocation of time		Permanent migration to urban areas, temporary employment off-farm, gathering NTFPs, work on farm, hiring labour	Yearly labour budget, "management constraint" on hired labour
Land use, forest product extraction		Areas under maize, beans, coffee, pasture (own use or rented); leaves of Chamedor Palm extracted from primary forest	Land clearing requirements of new crop areas; fallow requirements; no disinvestment for perennial crops
Financial resources		Short term and long term credit, cash carry-over	Own funds available, credit limits, interest rate, end-of-period replenishment of initial own funds

5.4.2.2. Decision variables

The farm household pursues its objective (to be described below, section 5.4.2.4) by choosing the level of different types of variables. A first group of variables refers to the allocation of time. As described above, these include permanent migration of one or more household members, temporary off-farm employment, hiring additional labour to complement family workforce, gathering plants and animals from natural or semi-natural areas. In terms of the latter activity, collection of Chamedor Palm has been explicitly included in the analysis, given the availability of detailed data on price and quantities of labour and other input requirements[36].

A second group of decision variables concerns land use and conversion decisions. These have been broken down into a few main types[37], i.e. maize, beans, coffee and pasture. Finally, there is a group of decision variable concerning the household's financial management. These include the level of short term and long-term (i.e., repayable at the end of the time horizon considered in the analysis) credit, as well as the amount of cash that the farm transfers from one year to the other.

In what follows, a different notation from the one used in section 5.4.1 will be adopted. This is both more compact, and consistent with symbols conventionally used in the linear programming literature: in each time period ***t***, x_i^t denotes the level of the generic i (i=1,..., n) activity variable selected by the farm household.

5.4.2.3. Constraints

The first set of constraint refers to the technical requirements for resource use:

$$\sum_{i=1}^{n} a_{ji} x_i^t \le b_j; \quad j = 1,\ldots,m; \; t = 1,\ldots,T$$

(5-3)

[36] Other gatherings of natural products may take place; see below for an analysis of the conditions under which this may happen.

[37] A variety of other crops are farmed at a lower scale in the region, including squash, chile, papaya, zapote, watermelon.

where x_i^t is the level of activity i at time t, a_{ji} is the corresponding technical requirement of input j, and b_j is the total amount of input k available to the farm[38]. Labour budgets fall in this category: these require that in any given time period, the sum of labour used by the different production activities does not exceed the total household's work time (given by the number of family members times an assumed annual working time of 300 days per individual) minus the amount of labour hired outside the household[39].

Another important group of resource constraints refers to the farm household's access to credit. It is assumed that this would be quite limited on account of the significant degree of overall imperfection of Mexico's rural credit markets (World Bank, 1995). Because of the likely inability of new household to offer collateral to formal financial institutions, it is assumed that they may only have limited access to credit from money lenders and/or friends or relatives. The conditions are likely to be quite unfavourable, in terms of low credit limits, short repayment periods and very high interest rates. The actual parameters used in the analysis have been borrowed from the World Bank's study on rural financial markets in Mexico referred to above.

In addition, and bearing in mind the earlier discussion on the adaptation of Low's model, the following further constraints are considered:

[38] Resource constraints are in general assumed to be time-invariant, unless otherwise indicated.

[39] The latter is further limited by a "management constraint", whereby the total amount of hired labour must not exceed a given proportion of the household's own labour: it may not be realistic to expect that small producers have the time and managerial resources to supervise hired labour in excess of, say, 50% of their own working time.

a) Maximin constraints:

$$\sum_{i=1}^{n} f_i^{ht} x_i^t \geq V_t; \quad h = 1,\dots,H; \; t = 1,\dots T+1$$

(5-4)

Here f_i^{ht} is a cash flow coefficient for activity x_i^t. This will be of course positive for inflows like wage income, receipt from sale of products, credit obtained, cash carried forward from previous years, and own funds; and will be negative for outflows like payment of fixed or variable factors, wage payments for hired labour, repayment of credit's interest and principal, cash carry forward to following years. V_t is the minimum value of the cash flow over the relevant set of states of nature {1,..., H}. This set of constraints ensures that under the optimal choice of x_i^t, the cash flow will be equal to V_t in the worst case, and larger than that in all other states of nature. Remembering the definition of H above, the total number of cash flow constraints will be 2^q (T+1); that is the total number of states of nature times the number of time periods plus the end-of period cash flow constraint.

b) Survival constraints

Once the maximin constraint are satisfied, it is further required that the net cash flow be sufficient to purchase a bundle of survival goods. What is the value and what the composition of such a bundle? A recent study of the World Bank(World Bank, 1996) provides estimates of extreme and moderate poverty lines[40] for rural Mexico. The first is the level of expenditure that guarantees adequate nutrition if all income is allocated to food. The moderate poverty line is a level of expenditure that permits not only purchase of food but also of other basic needs such as clothes, shelter and transport. Let us label S the moderate poverty line and S^0 the extreme poverty line, so that S^1=S - S^0 is the value of basic non-food expenditure.

[40] When borrowed for use in the model, these have been inflation-adjusted as appropriate.

As a compromise between appropriately representing survival constraints and not restricting too much the variables' feasibility region, the model provides a different treatment of the two poverty levels. It is assumed that the farm seeks to minimise the deviation from the moderate poverty line, subject to the constraint of at least meeting the extreme poverty line. If the extreme poverty bundle consists of n_0 goods (each them priced at p_{i_0}), the latter constraints are thus:

$$x_{i_0}^t \geq x_{i_0}^0;\ i_0 = 1,\ldots,n_0;\ t = 1,\ldots,T;\ \sum_{i_0=1}^{n_0} p_{i_0} x_{i_0}^t = S^0$$

Given dietary habits prevailing in the study area, , it is assumed that survival nutrition may be provided by consumption of maize and beans, the region's (and Mexico's) main sources of carbohydrates and proteins, respectively. At 1995 prices, a diet of 800 Kg of maize and 260 Kg of beans[41] per adult per year yields a value for S^0 close to the World Bank figure; these consumption levels are also not too distant from field observations (pointing to figures of 650 and 200 Kg for maize and beans, respectively).

To allow for the achievement of the moderate poverty line to be treated as a target, rather than a constraints, "artificial" indicators of deviation from the such goal are introduced. In every time period, the constraint representing the moderate poverty line becomes:

$$V_t + \Delta_t^{(-)} \geq S - \sum_{i_0=1}^{n_0} p_{i_0} x_{i_0}^t;\quad t = 1,\ldots,T$$

(5-5)

Here $\Delta_t^{(-)}$ indicates underachievements of (i.e. negative deviations from) the farm's set goal[42].

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[41] Calculated on the basis of the approximate ratio maize/ beans of 3 to 1 (in physical terms) obtained through field work.

[42] More generally, one can also consider overachievements of the farm's goals: for certain configurations of the feasible set, the farm household may be able to do better than just meeting the cash flow subsistence

5.4.2.4. Objective function

The farm's objective can finally be defined as follows:

$$Min\left[\sum_{t^{-}=1}^{T} w_{t^{-}}.\Delta_t^{(-)} - \overline{w}\sum_{i=1}^{n}\overline{c}_i x_i\right]$$

(5-6)

that is, the farm household is assumed to minimise the weighted sum of deviations from survival and prosperity targets. The w coefficients are weights reflecting the farms' set of priority among its different goals. The second term of (5-6 is the expected value of the farm's income, where:

$$\overline{c}_i = \frac{\sum_{j=1}^{J} c_i^j}{J}$$

The second term includes contribution to the farm's welfare, and thus needs to have a negative sign in a minimisation problem. The interpretation of (5-6 is that the farm household trades off attainment of minimum cash flow required for survival with longer term income maximisation.

5.4.2.5. Parameter selection

A number of decisions were made to establish a baseline case for the model, to be subsequently used to perform sensitivity analysis on a few parameters of particular analytical and policy significance. Table 5–2 lists the values of the parameters used in

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targets. However, the keep the model simple, it will be assumed in the next section that well-being improvement in excess of subsistence is included in the farm's objective through the total net present value of household's activities, rather than the period to period cash flow.

formulating the model's objective function and constraints. A few explanatory remarks follow on some key parameters.

Table 5–2: Parameters for baseline case

Name	Base Value	Units	Type	High	Low
Discount	15%				
Working days per adult	300	Working days per year			
Maize per adult per year	800	Kg			
Beans per adult per year	260	Kg			
Commuting_cost	25%	Percentage of time lost in commuting to urban jobs			
Time horizon after project	10	Years			
Baseline stocking rate	1.48	Animal unit/ ha			
Cow weight	400	Kg			
Yearly_working_days	300				
Duration LT credit	10	Years			
Childs per adult	0.5				
Child cash subsistence	0.3	In precent of adults cash needs			
Exc_rate	6.30	MexPes/ US$			
Maize_price	0.13	US$/ Kg			
Maize_purchase_price	0.13	US$/ Kg		0.13	0.18
Beans_price	0.51	US$/ Kg			
Beans_farmgate_price	0.51	US$/ Kg		1	0.01
Wage_rural	2.38	US$/ Day			
Wage_urban	3.17	US$/ Day			
Coffe_organ_price	0.68	US$/ Kg			
Coffee_trad_price	0.52	US$/ Kg			
Palma_extrac_price	0.48	US$/ Gruesa			
Maize_subsist	1840	Kg			
Beans_subsist	598	Kg			
Family_labor	600	Work days per year			
Family size	3.0	Number of individuals			
Family subsistence cash	1,495	US$/ year			
Milk price	0.14	US$/ Liter			
Cow price	0.71	US$/ Kg			
Torete price	0.76	US$/ Kg			
Novilla price	0.71	US$/ Kg			
Stocking rate	1.48	Animal unit/ ha			
Employment rate	25%			20%	5%
Borrowing rate	200%			20%	200%
Credit limit	200	US$		500	50
Palma Extrat price Pesos	3	MexPes/ gruesa		100%	0
Coffee_price_shock	0%			0	0.5
Own_funds	35	US$		100	0
Adults per family	2.0				
Cash Subsistence per adult	650	US$/ year			
Contingent parameters	4				
Demand for rented pasture	20%	Probability of pasture being requested for rental			

a) The number of adults (and thus workers) per family was set at 2, which is consistent with the objective of modelling a newly formed household. It is assumed that the newly formed household has already a child.

b) Total staple crops and cash requirement of the two-adults, one child household is then determined on the basis of field information relative to per capita annual consumption of maize and beans, and of the above mentioned World Bank figures on minimum subsistence expenditure.

c) The number of output prices subject to random variation was set at 4. This represents a compromise between realism and model size. On the one hand, the need for adequately representing the highly uncertain environment in which subsistence farmers operate would dictate that as many prices as possible should be considered random. On the other hand, the dimension of the models are significantly affected by the number of random output prices: even in the simple case considered here of variables with only two possible values -high price, low price-, adding one extra random variable to $\boldsymbol{n}$ pre-existing variables adds 2^n constraints. With four random prices, the dimensions of the model is of 70 variables in 108 constraints.

   In the baseline case, the four following prices were included as random: *chamedor* palm, beans, coffee, and the wage rate. The latter requires some additional explanation. From the household's point of view, the amount of labour that can be committed to temporary off-farm employment needs to be known at the beginning of the agricultural annual cycle. However, the demand for labour in the urban area is not known in advance, and so can be considered random from the farm household's standpoint. If $\boldsymbol{p}$ is the percentage of total household time $\boldsymbol{T}$ for which there will be demand in the off-farm sector, total revenues from non farm labour will be $\boldsymbol{wpT}$ where w is the wage rate. Therefore, the farm's revenue per unit of time is $\boldsymbol{wp}$ (that is, the farm will be able to obtain employment -remunerated at rate w-, $\boldsymbol{p}$ percent of the times). Different values of p will represent different levels of expected demand for labour. If the two (high, p^h, and low, p^l) levels of demand for labour are expected, returns from labour will vary between wp^h and wp^l.

d) Choice of the weights in the goal programming objective function. Subject to the constraint of adding up to 1, many combination of the four[43] weights included in (5-6) are possible. However, a plausible description of subsistence farming restricts considerably the range of possible choices. As it will be discussed in the rest of the section, in a fairly wide range of financial (credit, own resources) and profit margins parameters, the model's solution suggests that the farm household will not be able to eliminate the deviation of net cash flow from subsistence targets. In this range, it is quite unlikely that farmers will be concerned about the net present value of their activities over the entire time horizon considered. Rather, they will be more concerned about period to period survival. It is therefore assumed that $\overline{w}$ will start having non zero values only when the farm has enough own resources to meet survival objectives. As for the other weights, it is assumed that the underachievement variables have weights of 0.8, 0.1 and 0.1, respectively. This captures the idea that the farm attaches a high premium to immediate (next period) subsistence: the higher the chances of meeting subsistence target initially, the better the prospects for enduring worse times later.

e) Livestock parameters. Costs from, and returns to, livestock activities were derived through adjustment of FAO herd projections prepared in the context of the already mentioned GEF-funded case study. A key parameter in the calculation of the benefit stream from ranching is the stocking rate, i.e. the per hectare carrying capacity (in number of head of cattle) of pasture land. The stocking rate will be positively affected by accessibility and by the pasture's age and management: newly opened pasture areas with good access are likely to have higher rates than areas that have poor access and/ or with little or no investment in management measures to counteract overgrazing. A

[43] Considering equation (5-6), the four weights are given (as T=3), by three weights for the underachievemnts, plus one for the expected present value of total returns.

baseline stocking rate value for areas recently converted from forest was set to 1.4 Animal Units/Ha.

Regarding the pasture land's rental value, it is assumed that this is an annuity equivalent to the net present value of cattle ranching[44] over a 10 years time horizon. However, the actual returns to pasture land put on the rental market will depend upon the existence of a demand for such land. Any given hectare of newly converted pasture will have a chance of being rented if there are ranchers in reasonable proximity with excess cattle (either because they have purchased new cattle, or because existing pastures have been overgrazed). On top of geographical and ecological factors, the demand for rented pasture is also affected by financial variables: a rancher with cattle in excess of his pasture's carrying capacity may not be able to rent land if previously contracted debts[45] force him to liquidate part of his herd. In analogy with the treatment of the demand for off-farm labour, a parameter, $\boldsymbol{r}$, has been introduced in the analysis to describe the probability that a particular hectare of pasture will be requested for rent.

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[44] Including the value of the herd remaining at the end of the period considered.

[45] See section 5.2.4 for a brief discussion of the financial difficulties of some of the region's ranchers.

5.4.2.6. Results

The model was set up in *Excel* 5.0 for Windows (the complete model, including formulae to allow for variation of contingent parameters, spans across many pages of the spreadsheet; a reproduction of the basic structure is contained in Annex 5-2). Solution were found by applying *Excel*'s Solver package (results were validated through use of the functions LinearProgramming and ConstrainedMin in *Mathematica* 3.0 for Windows).

Table 5–3 New households: baseline case

Baseline:	Years			
	1	2	3	Total
Minumum level of own funds (US$)				45.0
Objective function (US$)				910.32
Deviation from moderate poverty line	63%	63%	38%	
NPV of gross expected margin (US$)				2,091.17
Pasture (has)	0.0	0.0	0.0	
Rented Pasture (has)	0.0	0.0	1.5	
Milpa (has)	5.1	5.1	0.7	
Total incremental land Clearance (has)	5.1	0.0	0.0	5.1
Coffee (has)	0.0	0.0	0.0	
Extraction of Chamedor Palm (gruesas)	766	3,582	4,640	8,989
Off-farm employment (days)	87.07	0	0	87
Short term credit (US$)	137.53	200.00	0	338
Long term credit (US$)	62.47			62

Baseline case

Table 5–3[46] reports some key results of the LP model run for the baseline case. In a scenario of poor employment prospects, variable coffee prices, limited and expensive access to

[46] A few remarks on this result table, as well as in the following ones. Lower values of the objective function correspond to higher level of farms well-being (the LP problem is a minimisation one); area under *milpa* includes plots of staple crops (maize and beans) as well as fallow land.

credit, full attainment of the moderate poverty line will not be possible. In fact, for level of own funds below the cut-off level of $45, no feasible solution to the model could be found: that is, farms with an initial endowment of wealth below $45 may not even be able to reach the extreme poverty line. This is indicative that alternative survival strategies may be adopted: for farms located in proximity of wilderness areas, these may consist of extraction of additional natural products on top of Chamedor Palm (which in the baseline case accounts for over 60% of the household labour's use on average).

Duality properties of linear programming can give an indication of the conditions under which an extra activity can be profitably undertaken by the farm household. At an optimum, the total opportunity cost[47] of producing a unit of a given product must be equal to the unit profit margin for that good. Assuming that extractive activities require labour as the only input, in any time period the minimum level of profit margins (per unit of labour) required for profitable production is given simply by the shadow wage rate for that time period. For the baseline case, this implies that the new extractive activity's profit margin must be at least of $2.1, $.0.3 and $0.2 for periods one to three, respectively[48].

For households with own resources in excess of the minimum level, subsistence is guaranteed by conversion of land to agriculture uses for about 5 has, and extraction of

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[47] Formally, the total opportunity cost of engaging in activity *i* is given by $\sum_{j=1}^{m} a_{ij} y_j$, where y_j is the shadow value of the j-th resource constraint.

[48] Detailed estimation of margins (per unit of labour) of gathering and hunting activities has not been attempted. However, evidence presented in chapter 4 (e.g. section 4.4.4.2) suggest that several plant (including Ixtle and Chocho) and animal species (like Parrots and Tucans) are good candidates for harvesting margins in the range of $0.5 - $2 per unit of labour.

Chamedor Palm over an area that can be estimated to cover around 10 has[49]. No conversion to pasture occurs, neither for the household's own use nor for rental purposes.

Off-site employment

What happens if the employment prospects off-site improve? This is can be assessed by running the model with more optimistic values for the high and low levels of labour demand. If the farm household expects to be able to find employment off-site between 40% and 60% of the times, its subsistence prospects improve in the way illustrated by Table 5–4

Table 5–4 New households: improved employment prospects

High Employement (chance of employment 40-60%):	Years			
	1	2	3	Total
Minumum level of own funds (US$)				0.1
Objective function (US$)				779.38
Deviation from moderate poverty line	57%	63%	0%	
NPV of gross expected margin (US$)				1,506
Pasture (has)	0.0	0.0	0.0	
Rented Pasture (has)	0.0	0.0	0.0	
Milpa (has)	0.7	0.7	0.7	
Total incremental land Clearance (has)	0.7	0.0	0.0	0.7
Coffee (has)	0.0	0.0	0.0	
Extraction of Chamedor Palm (gruesas)	(0)	1,780	0	1,780
Off-farm employment (days)	272	268	444	984
Short term credit (US$)	29.99	-	0	30
Long term credit (US$)	-			0

No minimum level of initial wealth is required to obtain a feasible solution; with respect to the baseline case, both the use of land for agriculture and the extraction of Chamedor Palm

[49] Assuming 9,000 plants/ha, 4 leaves per plant, and noting that 1 gruesa = 120 leaves.

decrease substantially; the household's level of indebtedness also decreases, as labour income substitutes borrowed funds in meeting cash flow constraints.

Credit

Another set of interesting results can be derived by modifying the parameter representing farmers' access to credit. Table 5–5 lists the results of the model under an hypothetical scenario in which subsistence farmers may obtain credit at substantially lower borrowing rates and higher credit limits: these have been set, for heuristic purposes, at levels of 20% and $500, respectively. The objective of this exercises is purely illustrative, so that issues related to provision of collateral , moral hazard and risk of default have not been addressed.

Table 5–5 New households: improved access to credit

Improved credit (rate of 20%, limit $500, w=6%):				
	1	2	3	Total
Minumum level of own funds (US$)				0.0
Objective function (US$)				125.27
Deviation from moderate poverty line	49%	63%	0%	
NPV of gross expected margin (US$)				9,426
Pasture (has)	0.0	0.0	0.0	
Rented Pasture (has)	0.0	3.3	3.3	
Milpa (has)	0.7	0.7	0.7	
Total incremental land Clearance (has)	0.7	3.3	0.0	4.0
Coffee (has)	0.0	0.0	0.0	
Extraction of Chamedor Palm (gruesas)	2,754	8,134	4,491	15,380
Off-farm employment (days)	-	0	0	0
Short term credit (US$)	-	500	500	1,000
Long term credit (US$)	500			500

The impact on household welfare is clear: the objective function improves over 110% with respect to the baseline case, in period 3 the target level of the moderate poverty line is achieved. Furthermore, a low or even zero level of initial endowment does not preclude attainment of financial equilibrium and subsistence objectives However, in the absence of specific incentives and/or changes in the relative prices of outputs, improved credit results in increased extraction of natural resources, while the pressure on land conversion does not disappear: about 4 has of land are cleared for milpa but mainly for rented pasture; the average extraction rate of palm increases to over 5,000 gruesas per year, which amounts to over 15 has of forested area being brought under extractive pressure.

Coffee

An example in which improved credit conditions, rather than encouraging conversion, result in use of forested area for shaded coffee production is illustrated in Table 5–6. This assumes an initial wealth endowment of $100 and a 8% weight[50] attributed to the expected income objective. Credit terms are the same of the previous example; what varies are the improved marketing prospects for coffee sales. In the baseline case, the price of coffee is assumed to be affected by a "shock" varying between 0 and 50%; here the range of variation of the price shock is assumed to be only 0-10%.

Table 5–6 New households: improved prospects for coffee production

Coffee production	Years			
	1	2	3	Total
Assumed level of own funds (US$)				100.0
Weight of expected income objective				8%
Objective function (US$)				135.91
Deviation from moderate poverty line	63%	63%	63%	
NPV of gross expected margin (US$)				11,111
Pasture (has)	0.0	0.0	0.0	
Rented Pasture (has)	0.0	0.0	0.0	
Milpa (has)	0.7	0.7	0.7	
Total incremental land Clearance (has)	0.7	0.0	0.0	0.7
Coffee (has)	0.4	0.4	0.4	
Extraction of Chamedor Palm (gruesas)	2,476	6,796	4,327	13599.7
Off-farm employment (days)	-	0	0	0.0
Short term credit (US$)	-	500	500	1000.0
Long term credit (US$)	500			500.0

[50] This is the minimum weight resulting in non zero values of coffee area.

About half a hectare of land under secondary forest is turned into coffee production; sensitivity analysis shows that the size of the coffee plot grows with the initial endowment of funds. Milpa area is reduced to a minimum, while extraction of Palm is lower than the previous case, but still higher than in the baseline.

Conclusions on the newly formed household model

The model suggests that newly formed farms with little financial resources of their own and limited (and expensive) access to credit, critically depend on intensive use of natural resources for their survival. Intensity of extraction of forest products and expansion of the agriculture frontier are quite sensitive to availability of off-farm employment opportunities; biodiversity - friendly uses of forested area like shaded coffee are unlikely in the absence of favourable conditions of access to credit and final output markets.

Using information on the vegetation cover and population's demographic structure, it is possible to construct aggregate projections of agriculture expansion and extractive pressure for the region's different administrative and zoning units. This exercise will be undertaken in the next chapter.

5.4.3. Evicted farmers

In addition to newly formed households, an extra source of pressure on natural resources is likely to come from those farmers with no formal title to land, who may be evicted as a result of the implementation of the PROCEDE program.

These households will find themselves in conditions similar to young farmers: they may face the choice of finding salaried employment in the region or in the urban sector, or encroaching, wherever possible, in forested spaces not subject to parcelling processes. Family sizes are likely to be larger than newly formed households, so that per-household demand for staple crops and farmland will also be larger. For those households who have enough own cash resources, an additional option may be to purchase parcels entering the land market as a result of the titling program.

Because of these similarities, the case of evicted farmers is studied here by simply running the newly formed farms model, with a larger family size (four instead of two adults). Not surprisingly, as shown in Table 5–7, baseline total incremental land clearance and Chamedor Palm extraction will both be higher than in the case of newly formed households. The minimum level of own funds required to ensure feasibility of the model is also considerably higher ($300).

Much as in the case of the newly formed households, improved prospects of off-site employment will clearly also impact evicted farmers' resource allocation. If the probability of finding employment, instead than averaging 25%, ranges between 25 and 75%, then over 50% on average of households' time is allocated to non-farm employment; land clearing for agricultural purposes decreases from 10 to 1.3 has; extraction of Chamedor Palm also decreases, from 6,000 to about 1,200 gruesas per year on average.

The next chapter will analyse the role of evicted households in determining pressure on land use and resource extraction.

Table 5–7: evicted farmers. Resource allocation in the baseline and high employment case

	Baseline case					High Employment case				
	Years					Years				
	1	2	3	Total	Average	1	2	3	Total	Average
Minimum level of own funds (US$)				300					0	
Objective function (US$)				1,391					1,406	
Deviation from moderate poverty line	63%	49%	0%			57%	63%	0%		
NPV of gross expected margin (US$)				0.00					0.00	
Pasture (has)	0.0	0.0	0.0			0.0	0.0	0.0		
Rented Pasture (has)	0.0	0.0	2.9			0.0	0.0	0.0		
Milpa (has)	10.2	10.2	1.3			1.3	1.3	1.3		
Total incremental land Clearance (has)	10.2	0.0	0.0	10.2		1.3	0.0	0.0	1.3	
Coffee (has)	0.0	0.0	0.0			0.0	0.0	0.0		
Extraction of Chamedor Palm (gruesas)	2,170	7,164	8,983	18,317	6,106	(0)	3,559	0	3,559	1,186
Off-farm employment (days)	111	-	-	111		544	536	888	1,968	656
Short term credit (US$)	87	53	-	140		60	-	0	60	
Long term credit (US$)	113			113		-			-	

5.4.4. Existing farms with land constraints

This model intends to represent resource allocation decisions in situations where encroachment in communal areas is not an option. This will be the case for households with a plot of land of their own, located in communities with little or no availability of communal spaces. As it was described in chapter 4, a typical individual holding of land consists of areas under *milpa* mainly for domestic production of staple crops, of areas under pastures, and possibly of remaining patches of primary forest and of second growth vegetation.

From the point of view of impact on biological resources, it is important to analyse the conditions under which the household will be induced to change the allocation of land from current uses entailing vegetation cover (primary forest or *monte,* second growth forest or *acahual*, shaded coffee) to uses that require land clearing (maize-based farm land or *milpa,* pasture).

It is also important to explore the reverse process, that is, to analyse the conditions under which the household may cease using cleared areas of land. As it will be discussed in detail in the final chapter, liberation of land currently under pasture may have an important function to play in the context of an integral strategy of biodiversity conservation and sustainable use. Land released from grazing may be left idle to allow for nutrients re-storing and regeneration of the vegetation cover; subsequently, it could be used for agriculture, or, in more advanced stages of the regeneration process, to help forming corridors between forest fragments.

Table 5-6. Transition matrix for land uses

USES ($time_{t+1}$)	SOURCES ($Time_t$)							
	Monte (M_t)	Acahual (A_t)	Coffee (C_t)	Maize (Mz_t)	Beans (B_t)	Pasture (P_t)	Idle Pasture (IP_t)	Total sources
Monte (M_{t+1})	Yes	No	No	No	No	No	No	$M_{t+1} \le M_t$
Acahual (Milpa)	No	Yes	Yes	Yes	Yes	No	No	$AM_{t+1} \le A_t + C_t + Mz_t + B_t + P_t$
Acahual (non milpa)	No	Yes	Yes	Yes	Yes	No	Yes	$Anm_{t+1} \le A_t + C_t + Mz_t + B_t + P_t$
Coffee (C_{t+1})	No	Yes	Yes	No	No	No	No	$C_{t+1} \le C_t + A_t$
Maize (Mz_{t+1})	Yes	Yes	Yes	Yes	Yes	No	No	$Mz_{t+1} \le Mz_t + B_t + ForestClean_{t+1} + AcahualClean_{t+1} + CoffeeClean_{t+1}$
Beans (B_{t+1})	Yes	Yes	Yes	Yes	Yes	No	No	$B_{t+1} \le Mz_t + B_t + ForestClean_{t+1} + AcahualClean_{t+1} + CoffeeClean_{t+1}$
Pasture (P_{t+1})	Yes	Yes	Yes	No	Yes	Yes	No	$P_{t+1} \le Mz_t + B_t + P_t$
Rented Pasture (R_{t+1})	Yes	Yes	Yes	Yes	Yes	Yes	No	$R_{t+1} \le P_t + B_t + Mz_t + ForestClean_{t+1} + AcahualClean_{t+1} + CoffeeClean_{t+1}$
New Pasture (NP_{t+1})	No	No	Yes	Yes	Yes	No	No	$NewPasture_{t+1} \le ForestClean_{t+1} + AcahualClean_{t+1} + CoffeeClean_{t+1}$
Idle Pasture (IP_{t+1})	No	No	No	No	No	Yes	Yes	$IP_{t+1} \le IP_t + P_t$
TOTALS:								
Flows (accretion of stocks)			$NewCoffee_{t+1} \le A_t$		$NP_{t+1} \le MonteClean_{t+1} + AcahualClean_{t+1} + CoffeeClean_{t+1}$			
Flows (depletion of stocks)	$ForestClean_{t+1} + M_{t+1} = M_t$	$AcahualClean_{t+1} + AM_{t+1} = A_t$	$CoffeeClean_{t+1} + C_{t+1} = C_t$				$IP_{t+1} = P_t - P_{t+1}$	
Total uses of stocks	$M_t \ge M_{t+1} + Mz_{t+1} + B_{t+1} + P_{t+1}$	$A_t \ge Anm_{t+1} + AM_{t+1} + C_{t+1} + Mz_{t+1} + B_{t+1} + P_{t+1}$	$C_t \ge Anm_{t+1} + AM_{t+1} + C_{t+1} + Mz_{t+1} + B_{t+1} + P_{t+1}$	$Mz_t = AM_{t+1} + Anm_{t+1} + Mz_{t+1} + B_{t+1} + P_{t+1}$	$B_t \ge AM_{t+1} + Anm_{t+1} + Mz_{t+1} + B_{t+1} + P_{t+1}$	$P_t \ge Anm_{t+1} + P_{t+1} + R_{t+1}$		
Total uses of flows	$ForestClean_{t+1} \ge Mz_{t+1} + B_{t+1} + NewPasture_{t+1} + R_{t+1}$	$AcahualClean_{t+1} \ge NewCoffee_{t+1} + Mz_{t+1} + B_{t+1} + NewPasture_{t+1} + R_{t+1}$	$CoffeeClean_{t+1} \ge Mz_{t+1} + B_{t+1} + NewPasture_{t+1} + R_{t+1}$					

Legend:

No change, and no conservation of vegetation	
No change, plus conservation of vegetation	
Conversion	
Regeneration	

Table 5–8 provides the basic conceptual framework underpinning the model. The column headings refer to stocks of different types of land at the generic time ***t***. The row headings refer to land stocks of at time ***t+1***. The "yes" cell intersections identify those transitions from one stock type to another which are included in the model[51]. These transitions, as illustrated by the legend, can be of four types: a) maintenance of land uses entailing no vegetation cover (milpa land under maize or beans, pasture); b) maintenance of land uses entailing vegetation cover (primary and secondary forest, coffee groves, milpa area under fallow); c) conversion; d) regeneration. So for example, land that was under primary forest in time ***t*** can turn into farm land (maize, beans) in time ***t+1*** through conversion; land that was under pasture in time t can be reclaimed for regeneration in time t+1, to start a process which will eventually result (either naturally or supported by human intervention) in formation of second growth forest[52].

The matrix provides the conceptual basis for the specification of a number of land use constraints in the LP model. These are reported in the last four rows and last column of the table. The flows which deplete or accrete stocks are defined in the fourth and third to last rows; of example, deforestation at time t+1 is the difference between Monte at times ***t*** and

[51] The "No" cells refer to transitions which are prevented either by irreversibility (e.g. regeneration of primary forest) or by technical reasons (e.g. use of grazing areas for crop production requires some preliminary repletion of soil's nutrient contents, clearing, so that the transition from pasture to milpa is assumed to be possible only via an intermediate transition to acahual).

[52] The time required for the transition from fallow land to second growth varies depending on a variety of climatic, altidudinal and edaphic factors. Furthermore, regeneration time will depend also on the definition of "second growth": later stages of the natural succession process will clearly require longer time than earlier ones. So the critical time will depend on the succession stage of interest for the particular management problem at hand. Based on evidence from tropical south east Asia, (Banerjee, 1995) reports appearence of pioneer species after a five years of fallow, while longer time (over 15 years) is necessary for a richer mosaic of species. It is also interesting that restoration of species diversity can be significantly accelerated and facilitated by human interventions, mainly trough plantation (Parrotta, 1993; Lugo, Parrotta et al., 1993).

t+1: $ForestClear_{t+1} = M_t - M_{t+1}$. The last two rows express constraints about the total uses of flows and of stocks. So, for example, in flow terms, forest land cleared in time t+1 must be turned in one or more of the following uses: maize, beans, new pasture, rented pasture: $ForestClear_{t+1} \geq Mz_{t+1} + B_{t+1} + NewPasture_{t+1} + R_{t+1}$. In terms of stocks, forested land in time t must be devoted to one or more of the following uses in time t+1: forested land, maize, beans, new pasture: $M_t \geq M_{t+1}+Mz_{t+1}+B_{t+1}+NP_{t+1}$.

The last column formulates constraints about the sources of stocks at time t+1 in terms of stocks of land types at time t. For example, pasture rented in time t+1 must not exceed the sum of already cleared areas (maize, beans and pasture at time t) plus the sum of newly cleared areas (primary and secondary forest, coffee groves cleared at time t+1): $R_{t+1} \leq P_t + B_t + Mz_t + ForestClear_{t+1} + AcahualClear_{t+1} + CoffeeClear_{t+1}$.

The model's other basic characteristics (objective function, treatment of risk, types of decision variables) are the same of the newly formed households model. A brief discussion explaining the specific choice of a few key parameters follows.

a) The number of adults is set at 4, and the overall family size (including children below the minimum working age) is at 6. This figures are broadly consistent with average family sizes in different parts of the study area as discussed in chapter 4.

b) Extraction of Chamedor Palm is still included in the model, but is contingent upon patches of primary forest being present in the household's parcel. That is, no extraction from communal areas takes place.

c) The number of random parameters was decreased from 4 to 3: beans, coffee, and the wage rate. The matrix of land use transition entails a significant number of additional constraints, so that a reduction in the number of the cash was necessary to keep the model within manageable limits. As Palm extraction is likely to play a minor role in the income of households described by this model, it seemed reasonable not to include its price in the group of parameters subject to random variation.

d) Farmland and cattle herds may be used as collateral for credit. Therefore, households owning these assets are likely to have access to better credit conditions than newly formed households. Following again the analysis of the above mentioned study on rural financial markets (World Bank, 1995), it is assumed that households being described in this model have access to credit from the "formal" sector (banks, chartered non-banks and other registered institutions) as opposed to newly formed household who were assumed to have only access to the "informal" credit sector (friends and relatives, moneylenders).

e) Based on the data presented in chapter 4, an initial allocation of land was used for a paradigm household with a total holding of 28 has. The assumed break-down of uses is reported in Table 5–9.

Table 5–9: paradigm farm, assumed initial allocation of land

Land use	Has
Maize	2.0
Beans	0.5
Monte	5.0
Pasture	15.0
Coffee	1.5
Acahual	4.0
Total	28.0

Results

In a baseline scenario, settled farms are unlikely to be a major source of land use change. As illustrated by Table 5–10, the model suggests a total of 1.30 has of land clearance, which is used for increasing rented pasture (assuming a probability of demand for pasture land of 50%). Milpa production requires on average 4 has of land; household labour is partly allocated to non-farm activities: collection of forest products (an average of 1,140 gruesas per year, corresponding to about 10% of total working time), and temporary employment off-site (average of 500 days per year, about 40% of total household labour).

Table 5–10: Settled farms, baseline case

	Years			
	1	2	3	Total
Minimum level of own funds (US$)				0
Objective function (US$)				(1,288)
Deviation from moderate poverty line	59%	63%	63%	
NPV of gross expected margin (US$)				8,451
Pasture (has)	15.00	16.44	15.00	15.48
Rented Pasture (has)	0	1.44	0	
Milpa (has)	2.56	5.06	6.50	4.70
Total incremental land Clearance (has)	0.00	1.44	(0.00)	1.44
Coffee (has)	1.5	1.5	1.5	1.50
Extraction of Chamedor Palm (gruesas)	340	2,752	340	1,144
Off-farm employment (days)	501	367	652	507
Short term credit (US$)	0	565	2,000	855
Long term credit (US$)				272

Improved prospects for cattle ranching

As discussed towards the end of section 5.2.4, cattle ranching activities in areas like the Sierra face a situation of crisis in the present, but of potential expansion in the future. The drop in incomes that followed the 1994 devaluation has been depressing demand for meat; the elimination of a number of subsidies has left several ranchers in a situation of heavy indebtedness. At the same time, the devaluation may help raise competitiveness, in the medium to long run, assuming easier access to export markets under NAFTA. When income will start picking up again, will this put pressure on the forest margins?

Chapter 6 will analyse the impact of income growth on ranching via increases in the demand or meat and diary products. To assess the land use impacts at the farm level, one needs to hypothesise the adjustment mechanism. If income growth induces an increase in the demand for livestock products, their prices are likely to increase in the short run, that is, until herd sizes adjust to the new levels of demand; prices may rise even more if the market share of low-input ranching increases at the expenses of the devaluation-penalised high inputs ranching from other parts of the country.

Table 5–11: settled farms, improved livestock prospects

Livestock expansion (100% probability of renting pasture, increase in livestock prices of 60%				
	Years			
	1	2	3	Total
Minimum level of own funds (US$)				0
Objective function (US$)				(124)
Deviation from moderate poverty line	14%	63%	63%	
NPV of gross expected margin (US$)				12,076
Pasture (has)	15.00	18.25	18.25	17.17
Rented Pasture (has)	-	3.25	3.25	
Milpa (has)	0.75	3.25	3.25	2.42
Total incremental land Clearance (has)	0.00	3.25	-	3.25
Coffee (has)	1.50	1.50	1.50	1.50
Extraction of Chamedor Palm (gruesas)	340	2,752	340	1,144
Off-farm employment (days)	501	251	719	491
Short term credit (US$)	0	555	2,000	852
Long term credit (US$)				993

The impact of on land use of higher demand for livestock products is estimated here by assuming a short-run increase in prices (and thus, for given costs, of prospective profit margins). For the farm studied here[53], a 60% increase in the output price of beef and dairy[54] generates the results presented in Table 5–11: total land clearing more than doubles with respect to the baseline case, raising to 3.25 has per household: cleared area is used for increased pasture (for rental, rather than direct use by the farm).

[53] The level of price increase needed to trigger a land use reponse is likely to depend, among other factors, on the stocking rate of the farm's pasture. In ranches with higher stocking rates than the level considered here (0.8 AU/ha)., land use responses are likely to be generated by lower increase in output prices.

[54] It is plausible that improved prospects for ranching would also be reflected in the market for rented pasture; the analysis therefore assumes that the farm would be able to rent pasture, if it wished to do so, with probability equal to one.

Options for regenerating pasture lands

As discussed in chapter 4, in several areas of the Sierra ranching is a very land-extensive activity, that has been quickly displacing other forms of land use such as agriculture and forests. How could the land use intensity of pasture be reduced, so as to make more space available for agriculture or vegetation regeneration? As chapter 6 will discuss, there may be a range of possibilities, including the adoption of technologies that increase the stocking rate, so that if herds don't vary, the same number of heads of cattle can be sustained in less space.

A different route, which can be explored within the present model, refers to chapter two's discussion of compensation mechanisms for foregone uses of land. What would be the payment (provided through arrangements like tradable development rights or franchise agreements) that may induce the farm studied here to leave pasture land idle? It turns out that for rents below \$100 per her, no land is set aside for regeneration. Table 5–12 illustrates the farm's allocation of land for that value of the rental payment.

Table 5–12: settled farms with compensation for foregone land use

	Years			
	1	2	3	Total
Minimum level of own funds (US$)				0
Objective function (US$)				(686)
Deviation from moderate poverty line	37%	63%	63%	
NPV of gross expected margin (US$)				10,599
Pasture (has)	15.00	8.13	2.34	8.49
Rented Pasture (has)	-	0.63	2.34	
Milpa (has)	(0.00)	2.50	9.37	3.96
Total incremental land Clearance (has)	-	0.63	1.09	1.72
Coffee (has)	1.50	1.50	1.50	1.50
Extraction of Chamedor Palm (gruesas)	340	2,752	266	1,119
Off-farm employment (days)	501	492	538	510
Short term credit (US$)	263.866	0	2,000	755
Long term credit (US$)				270
Idle pasture land	0.0	7.5	7.5	
Acahual (has)	4.0	3.4	3.4	
Rent for Idle land (US$/ ha)				100

Much as for the case of new and evicted households, the results of the LP model for existing households will be used, in next chapter, to construct aggregate projections of land use.

Annex 5-1: deriving "corrected" profit margins

Given a series of profit margin with a generic term c_i for time i (i=1, 2, ... T), it is always possible to decompose the present value of the series in two components, one including the margins accruing before the generic time τ, and one including the subsequent ones:

$$\sum_{i=1}^{T}\frac{c_i}{(1+r)^i}=\sum_{i=1}^{\tau-1}\frac{c_i}{(1+r)^i}+\sum_{j=\tau}^{T}\frac{c_j}{(1+r)^j}$$

The second summation in the RHS is equivalent to a "corrected" margin, $\hat{c}_\tau$, which solves the equation:

$$\sum_{i=1}^{\tau-1}\frac{c_i}{(1+r)^i}+\frac{\hat{c}_\tau}{(1+r)^\tau}=\sum_{i=1}^{T}\frac{c_i}{(1+r)^i}$$

From this, it is straightforward to obtain the value of $\hat{c}_\tau$ actually used in the model:

$$\frac{\hat{c}_\tau}{(1+r)^\tau}=(1+r)\sum_{k=\tau}^{T}\frac{c_k}{(1+r)^{k-\tau+1}}\frac{1}{(1+r)^\tau}$$

Relevant parameter in contingency table?	Yes	Yes	No	No	No	No	No	No	No	Yes	No	No	Yes	No	No	No	No	Yes	No	No	Yes
Total dec var 71	1 00	1 00								2.00			3					4 0			1 00
NonZero Dec Var 39											Year 1										
Constraints 108	(Adults)	(Days)	(Has)	(Has)	(Has)	(kg)	(kg)	(kg)	(Has)	(kg)	(kg)	(kg)	(Has)	(Has)	(Has)	(Days)	(Days)	(Gruesas)	(US$)	(US$)	(Adults)
No conting parm 4	PermOff1	TempOff1	ForestClear	FallowMaize	Maize1	MaizeSale	MaizeCons	MaizeBuy	Beans1	BeansSal	BeansCon	BeansBuy	Coffee1	Pasture1	RentPastu	HireLabor1	Palma1	PalmaSal	Credit1	Transfer1	PermOff2
58	0 0	87 1	5 1	2 9	1 5	0 0	1,840 0	0.0	0 7	0 0	598 0	0 0	0 0	0 0	0 0	0 0	94 7	766 4	137 5	0 0	0 0
Year	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1 00
Margin	273 81	0 79	(48 46)		(7 96)	0 13		(0 13)	(11 90)	0 51		(0 51)	(209 21)	(388 78)	50 46	(2 38)	(0 96)	0 5	(2 00)		273 81
Discounted Objective	273 81	0 79	(48 46)		(7 96)	0 13	-	(0 13)	(11 90)	0 51	-	(0 51)	(209 21)	(388 78)	50 46	(2 38)	(0 96)	0 5	(2 00)		238 10
Revised Objective (model b)																					
Revised Objective (model c)																					
Goal Programming																					
	-1																				
ExpMargin	-136 90	-0 40	48 46	0 00	7 96	-0 13	0 00	0.13	11 90	-0 26	0 00	0 51	209 21	388 78	-50 46	2.38	0 96	-0 71	2 00	0 00	-119 05
Labor1	300 00	1 25	46 00	0 00	79 90	0 00	0 00	0 10	68 00	0 00	0 00	0 00	88 00	75 50		-1 00	1 00	0 00	0 00	0 00	0 00
ManagLabor1	0 75	0 75	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		1 00	0 00	0 00	0 00	0 00	0 00
RotatMaize1	0 00	0 00	0 00	-0 50	1 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		1 00	0 00	0 00	0 00	0 00	0 00
ClearedArea1	0 00	0 00	-1 00	1 00	1 00	0 00	0 00	0 00	1 00	0 00	0 00	0 00	0 00	0 00	1 00	0 00	0 00	0 00	0 00	0 00	0 00
MaizeBalance1	0 00	0 00	0 00	0 00	-1250 00	1 00	1 00	-1 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
BeansBalance1	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	-900 00	1 00	1 00	-1 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
PalmaBalance1	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	-8 10	1 00	0 00	0 00	0 00
SubsistMaiz1	0 00	0 00	0 00	0 00	0 00	0 00	-1 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
SubsistBeans1	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	-1 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
CreditLimit1	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	1 00	0 00	0 00
Labor2	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	300 00
ManagLabor2	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 75
RotatMaize2	0 00	0 00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
ClearedArea2					-1 00				-1 00						-1 00						
MaizeBalance2	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
BeansBalance2	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
PalmaBalance2	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
SubsistMaiz2	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
SubsistBeans2	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
CreditLimit2	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
Labor3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
ManagLabor3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
RotatMaize3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
ClearedArea3																					
MaizeBalance3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
BeansBalance3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
PalmaBalance3	0 00	0 00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
SubsistMaiz3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
SubsistBeans3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
CreditLimit3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
CattleBalance	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
PermMigr1	1 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
PermMigr2	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
PermMigr3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	1 00
CashSubsist1	0 00	0 00	0 00	0 00	0 00	0.00	0 00	0.00	0 00	0 00	0.00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
CashSubsist2	0 00	0 00	0 00	0 00	0 00	0 00	0.00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
CashSubsist3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
MaizePlot1to2	0 00	0 00	0 00	0 00	-1 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
MaizePlot2to3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
PastureArea1to2	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	-1 00		0 00	0 00	0 00	0 00	0 00	0 00
CoffeeArea1to2	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	-1 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
PastureArea2to3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
CoffeeArea2to3	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00		0 00	0 00	0 00	0 00	0 00	0 00
Cash flow 1 Event_1	0 00	-0.63	48 46	0 00	3 20	0 00	0 00	0 13	11 90	0 00	0 00	0 51	209 21	388 78	0 00	2 38	0 96	-0 24	-1 00	1 00	0 00
Cash flow 2 Event_1	-219.05	0 00	0 00	0 00	0 00	-0.13	0 00	0 00	0 00	-0 51	0 00	0 00	0 00	0 00	-50 46	0 00	0 00	-0.71	3 00	-1.00	0 00
Cash flow 3 Event_1	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	-219 05
Cash flow 4 Event_1	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00

Relevant parameter in contingency table?	Yes	No	No	No	No	No	No	No	Yes	No	No	Yes	No	No	No	No	Yes	No	No	Yes	Yes
Total dec var 71	1.00								2.00			3					4.0			1.00	1.00
NonZero Dec Var 39									Year 2												
Constraints 108	(Days)	(Has)	(Has)	(Has)	(kg)	(kg)	(kg)	(Has)	(kg)	(kg)	(kg)	(Has)	(Has)	(Has)	(Days)	(Days)	(Gruesas)	(US$)	(US$)	(Adults)	(Days)
No conting parm 4	TempOff2	ForestCle	FallowMa	Maize2	MaizeSale	MaizeCons	MaizeBuy	Beans2	BeansSal	BeansCon	BeansBuy	Coffee2	Pasture2	RentPastu	HireLabor	Palma2	PalmaSal	Credit2	Transfer2	PermOff3	TempOff3
58	0.0	0.0	2.9	1.5	0.0	1,840.0	368.0	0.7	0.0	598.0	0.0	0.0	0.0	0.0	0.0	442.5	3,582.2	200.0	0.0	0.0	0.0
Year	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00
Margin	0.79	(48.46)		(7.96)	0.13		(0.13)	(11.90)	0.51		(0.51)	94.44	49.49	50.46	(2.38)	(0.96)	0.48	(2.00)		273.81	0.79
Discounted Objective	0.69	(42.14)	-	(6.92)	0.11	-	(0.11)	(10.35)	0.44	-	(0.44)	82.13	43.04	43.88	(2.07)	(0.84)	0.41	(1.74)	-	207.04	0.60
Revised Objective (model b)																					
Revised Objective (model c)																					
Goal Programming																					
ExpMargin	-0.35	42.14	0.00	6.92	-0.11	0.00	0.11	10.35	-0.22	0.00	0.44	-59.35	-43.04	-43.88	2.07	0.84	-0.62	1.74	0.00	-103.52	-0.30
Labor1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
ManagLabor1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
RotatMaize1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
ClearedArea1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
MaizeBalance1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
BeansBalance1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
PalmaBalance1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
SubsistMaiz1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
SubsistBeans1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
CreditLimit1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor2	1.25	0.00	0.00	76.30	0.00	0.00	0.00	68.00	0.00	0.00	0.00	44.00	12.00		-1.00	1.00	0.00	0.00	0.00	0.00	0.00
ManagLabor2	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		1.00	0.00	0.00	0.00	0.00	0.00	0.00
RotatMaize2	0.00	0.00	-0.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
ClearedArea2		-1.00		1.00				1.00						1.00							
MaizeBalance2	0.00	0.00	0.00	-1000.00	1.00	1.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
BeansBalance2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-900.00	1.00	1.00	-1.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
PalmaBalance2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	-8.10	1.00	0.00	0.00	0.00	0.00
SubsistMaiz2	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
SubsistBeans2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
CreditLimit2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	1.00	0.00	0.00	0.00
Labor3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	300.00	1.25
ManagLabor3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.75	0.75
RotatMaize3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
ClearedArea3				-1.00				-1.00						-1.00							
MaizeBalance3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
BeansBalance3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
PalmaBalance3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
SubsistMaiz3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
SubsistBeans3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
CreditLimit3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
CattleBalance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
PermMigr1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
PermMigr2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
PermMigr3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	1.00	0.00
CashSubsist1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
CashSubsist2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
CashSubsist3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
MaizePlot1to2	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
MaizePlot2to3	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
PastureArea1to2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
CoffeeArea1to2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
PastureArea2to3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
CoffeeArea2to3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 1 Event_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 2 Event_1	**-0.63**	**48.46**	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	10.32	**-49.49**	0.00	2.38	0.96	-0.24	**-1.00**	1.00	0.00	0.00
Cash flow 3 Event_1	0.00	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.51	0.00	0.00	-104.76	0.00	-50.46	0.00	0.00	-0.71	3.00	-1.00	0.00	-0.63
Cash flow 4 Event_1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Relevant parameter in contingency table?	No	No	No	No	No	No	No	Yes	No	No	Yes	No	No	No	No	Yes	No	No	No	No	No
Total dec var 71								2.00			3					4.0					
NonZero Dec Var 39									Year 3												
Constraints 108	(Has)	(Has)	(Has)	(kg)	(kg)	(kg)	(Has)	(kg)	(kg)	(kg)	(Has)	(Has)	(Has)	(Days)	(Days)	(Gruesas)	(Kg)	(US$)	(US$)	(US$)	(US$)
No conting parm 4	ForestClear	FallowMa	Maize3	MaizeSale	MaizeCons	MaizeBuy	Beans3	BeansSal	BeansCon	BeansBuy	Coffee3	Pasture3	RentPastu	HireLabor	Palma3	PalmaSal	CattleSale	Credit3	LTCredit3	Transfer3	V1
58	0.0	0.0	0.0	0.0	1,840.0	1,840.0	0.7	0.0	598.0	0.0	0.0	0.0	1.5	18.4	573.2	4,640.5	0.0	0.0	62.5	0.0	0.0
Year	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	
Margin	(48.46)		(7.96)	0.13		(0.13)	(11.90)	0.51		(0.51)	4,882.3	924.08	50.46	(2.38)	(0.96)	0.48	0.71	(2.00)	(26.00)	$2.59	
Discounted Objective	(36.64)	-	(6.02)	0.10	-	(0.10)	(9.00)	0.38	-	(0.38)	3,691.8	698.74	38.16	(1.80)	(0.73)	0.36	0.54	(1.51)	(19.66)	1.96	
Revised Objective (model b)																					1.00
Revised Objective (model c)																					
Goal Programming																					
ExpMargin	36.64	0.00	6.02	-0.10	0.00	0.10	9.00	-0.19	0.00	0.38	-2768.82	-698.74	-38.16	1.80	0.73	-0.54	-0.54	1.51	19.66	-1.96	0.00
Labor1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ManagLabor1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RotatMaize1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ClearedArea1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MaizeBalance1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BeansBalance1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PalmaBalance1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SubsistMaiz1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SubsistBeans1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CreditLimit1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Labor2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ManagLabor2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RotatMaize2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ClearedArea2	0.00																				
MaizeBalance2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BeansBalance2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PalmaBalance2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SubsistMaiz2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SubsistBeans2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CreditLimit2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labor3	0.00	0.00	77.70	0.00	0.00	0.00	68.00	0.00	0.00	0.00	52.00	12.00		-1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
ManagLabor3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RotatMaize3	0.00	-0.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ClearedArea3	-1.00		1.00				1.00						1.00								
MaizeBalance3	0.00	0.00	-800.00	1.00	1.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BeansBalance3	0.00	0.00	0.00	0.00	0.00	0.00	-900.00	1.00	1.00	-1.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PalmaBalance3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	-8.10	1.00	0.00	0.00	0.00	0.00	0.00
SubsistMaiz3	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SubsistBeans3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CreditLimit3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
CattleBalance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-592.00		0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
PermMigr1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PermMigr2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PermMigr3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CashSubsist1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00
CashSubsist2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CashSubsist3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MaizePlot1to2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MaizePlot2to3	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PastureArea1to2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CoffeeArea1to2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PastureArea2to3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CoffeeArea2to3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 1 Event_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	1.00
Cash flow 2 Event_1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 3 Event_1	48.46	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	0.00	-191.82	0.00	2.38	0.96	-0.24	0.00	-1.00	0.00	1.00	0.00
Cash flow 4 Event_1	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.51	0.00	0.00	-523.81	0.00	-50.46	0.00	0.00	-0.71	-0.71	3.00	27.00	-1.00	0.00

NonZero Dec Var 39	Year 1																				
Constraints 108	(Adults)	(Days)	(Has)	(Has)	(Has)	(kg)	(kg)	(kg)	(Has)	(kg)	(kg)	(kg)	(Has)	(Has)	(Has)	(Days)	(Days)	(Gruesas)	(US$)	(US$)	(Adults)
No conting parm 4	PermOff1	TempOff1	ForestClear	FallowMaize	Maize1	MaizeSale	MaizeCons	MaizeBuy	Beans1	BeansSal	BeansCon	BeansBuy	Coffee1	Pasture1	RentPastu	HireLabor1	Palma1	PalmaSal	Credit1	Transfer1	PermOff2
58	0.0	87.1	5.1	2.9	1.5	0.0	1,840.0	0.0	0.7	0.0	598.0	0.0	0.0	0.0	0.0	0.0	94.7	766.4	137.5	0.0	0.0
Cash flow 2 Event_2	-219.05	0.00	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	-50.46	0.00	0.00	-0.71	3.00	-1.00	0.00
Cash flow 3 Event_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-219.05
Cash flow 4 Event_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 1 Event_3	0.00	-0.63	48.46	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	209.21	388.78	0.00	2.38	0.96	-0.12	-1.00	1.00	0.00
Cash flow 2 Event_3	-219.05	0.00	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.51	0.00	0.00	0.00	0.00	-50.46	0.00	0.00	-0.36	3.00	-1.00	0.00
Cash flow 3 Event_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-219.05
Cash flow 4 Event_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 1 Event_4	0.00	-0.63	48.46	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	209.21	388.78	0.00	2.38	0.96	-0.12	-1.00	1.00	0.00
Cash flow 2 Event_4	-219.05	0.00	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	-50.46	0.00	0.00	-0.36	3.00	-1.00	0.00
Cash flow 3 Event_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-219.05
Cash flow 4 Event_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 1 Event_5	-	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	209.21	388.78	0.00	2.38	0.96	(0.2)	(1.00)	1.00	-
Cash flow 2 Event_5	(54.76)	-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	-	-	-50.46	-	-	(0.7)	3.00	(1.00)	-
Cash flow 3 Event_5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)
Cash flow 4 Event_5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-
Cash flow 1 Event_6	-	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	209.21	388.78	0.00	2.38	0.96	(0.2)	(1.00)	1.00	-
Cash flow 2 Event_6	(54.76)	-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	-	-	-50.46	-	-	(0.7)	3.00	(1.00)	-
Cash flow 3 Event_6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)
Cash flow 4 Event_6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-
Cash flow 1 Event_7	-	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	209.21	388.78	0.00	2.38	0.96	(0.1)	(1.00)	1.00	-
Cash flow 2 Event_7	(54.76)	-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	-	-	-50.46	-	-	(0.4)	3.00	(1.00)	-
Cash flow 3 Event_7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)
Cash flow 4 Event_7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-
Cash flow 1 Event_8	-	(0.63)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	209.21	388.78	0.00	2.38	0.96	(0.1)	(1.00)	1.00	-
Cash flow 2 Event_8	(219.05)	-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	-	-	-50.46	-	-	(0.4)	3.00	(1.00)	-
Cash flow 3 Event_8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(219.05)
Cash flow 4 Event_8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-
Cash flow 1 Event_9	-	(0.63)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	209.21	388.78	0.00	2.38	0.96	(0.2)	(1.00)	1.00	-
Cash flow 2 Event_9	(219.05)	-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	-	-	-50.46	-	-	(0.7)	3.00	(1.00)	-
Cash flow 3 Event_9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(219.05)
Cash flow 4 Event_9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-
Cash flow 1 Event 10	-	(0.63)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	209.21	388.78	0.00	2.38	0.96	(0.2)	(1.00)	1.00	-
Cash flow 2 Event 10	(219.05)	-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	-	-	-50.46	-	-	(0.7)	3.00	(1.00)	-
Cash flow 3 Event_10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(219.05)
Cash flow 4 Event_10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-
Cash flow 1 Event_11	-	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	209.21	388.78	0.00	2.38	0.96	(0.2)	(1.00)	1.00	-
Cash flow 2 Event_11	(54.76)	-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	-	-	-50.46	-	-	(0.7)	3.00	(1.00)	-
Cash flow 3 Event_11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)
Cash flow 4 Event_11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-
Cash flow 1 Event_12	-	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	209.21	388.78	0.00	2.38	0.96	(0.2)	(1.00)	1.00	-
Cash flow 2 Event_12	(54.76)	-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	-	-	-50.46	-	-	(0.7)	3.00	(1.00)	-
Cash flow 3 Event_12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)
Cash flow 4 Event_12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-
Cash flow 1 Event_13	-	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	209.21	388.78	0.00	2.38	0.96	(0.1)	(1.00)	1.00	-
Cash flow 2 Event_13	(54.76)	-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	-	-	-50.46	-	-	(0.4)	3.00	(1.00)	-
Cash flow 3 Event_13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)
Cash flow 4 Event_13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-
Cash flow 1 Event_14	-	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	209.21	388.78	0.00	2.38	0.96	(0.1)	(1.00)	1.00	-
Cash flow 2 Event_14	(54.76)	-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	-	-	-50.46	-	-	(0.4)	3.00	(1.00)	-
Cash flow 3 Event_14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)
Cash flow 4 Event_14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-
Cash flow 1 Event_15	-	(0.63)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	209.21	388.78	0.00	2.38	0.96	(0.1)	(1.00)	1.00	-
Cash flow 2 Event_15	(219.05)	-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	-	-	-50.46	-	-	(0.4)	3.00	(1.00)	-
Cash flow 3 Event_15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(219.05)
Cash flow 4 Event_15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-
Cash flow 1 Event_16	-	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	209.21	388.78	0.00	2.38	0.96	(0.1)	(1.00)	1.00	-
Cash flow 2 Event_16	(54.76)	-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	-	-	-50.46	-	-	(0.4)	3.00	(1.00)	-
Cash flow 3 Event_16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)
Cash flow 4 Event_16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-

NonZero Dec Var 39 Constraints 108 No conting parm 4	(Days) TempOff2	(Has) ForestCle	(Has) FallowMa	(Has) Maize2	(kg) MaizeSale	(kg) MaizeCons	(kg) MaizeBuy	(Has) Beans2	(kg) BeansSal	(kg) BeansCon	(kg) BeansBuy	(Has) Coffee2	(Has) Pasture2	(Has) RentPastu	(Days) HireLabor	(Days) Palma2	(Gruesas) PalmaSal	(US$) Credit2	(US$) Transfer2	(Adults) PermOff3	(Days) TempOff3
	Year 2																				
58	0.0	0.0	2.9	1.5	0.0	1,840.0	368.0	0.7	0.0	598.0	0.0	0.0	0.0	0.0	0.0	442.5	3,582.2	200.0	0.0	0.0	0.0
Cash flow 2 Event_2	-0.63	48.46	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	10.32	-49.49	0.00	2.38	0.96	-0.24	-1.00	1.00	0.00	0.00
Cash flow 3 Event_2	0.00	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.01	0.00	0.00	-52.38	0.00	-50.46	0.00	0.00	-0.71	3.00	-1.00	0.00	-0.63
Cash flow 4 Event_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-219.05	0.00
Cash flow 1 Event_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 2 Event_3	-0.63	48.46	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	10.32	-49.49	0.00	2.38	0.96	-0.12	-1.00	1.00	0.00	0.00
Cash flow 3 Event_3	0.00	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.51	0.00	0.00	-52.38	0.00	-50.46	0.00	0.00	-0.36	3.00	-1.00	0.00	-0.63
Cash flow 4 Event_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-219.05	0.00
Cash flow 1 Event_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 2 Event_4	-0.63	48.46	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	10.32	-49.49	0.00	2.38	0.96	-0.12	-1.00	1.00	0.00	0.00
Cash flow 3 Event_4	0.00	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.01	0.00	0.00	-104.76	0.00	-50.46	0.00	0.00	-0.36	3.00	-1.00	0.00	-0.63
Cash flow 4 Event_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-219.05	0.00
Cash flow 1 Event_5	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_5	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.24)	(1.00)	1.00	-	-
Cash flow 3 Event_5	-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(104.76)	-	-50.46	-	-	(0.71)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_5	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_6	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_6	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.24)	(1.00)	1.00	-	-
Cash flow 3 Event_6	-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(52.38)	-	-50.46	-	-	(0.71)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_6	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_7	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_7	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.12)	(1.00)	1.00	-	-
Cash flow 3 Event_7	-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(104.76)	-	-50.46	-	-	(0.36)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_7	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_8	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_8	(0.63)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.12)	(1.00)	1.00	-	-
Cash flow 3 Event_8	-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(104.76)	-	-50.46	-	-	(0.36)	3.00	(1.00)	-	(0.63)
Cash flow 4 Event_8	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(219.05)	-
Cash flow 1 Event_9	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_9	(0.63)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.24)	(1.00)	1.00	-	-
Cash flow 3 Event_9	-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(52.38)	-	-50.46	-	-	(0.71)	3.00	(1.00)	-	(0.63)
Cash flow 4 Event_9	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(219.05)	-
Cash flow 1 Event_10	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_10	(0.63)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.24)	(1.00)	1.00	-	-
Cash flow 3 Event_10	-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(104.76)	-	-50.46	-	-	(0.71)	3.00	(1.00)	-	(0.63)
Cash flow 4 Event_10	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(219.05)	-
Cash flow 1 Event_11	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_11	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.24)	(1.00)	1.00	-	-
Cash flow 3 Event_11	-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(104.76)	-	-50.46	-	-	(0.71)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_11	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_12	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_12	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.24)	(1.00)	1.00	-	-
Cash flow 3 Event_12	-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(52.38)	-	-50.46	-	-	(0.71)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_12	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_13	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_13	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.12)	(1.00)	1.00	-	-
Cash flow 3 Event_13	-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(104.76)	-	-50.46	-	-	(0.36)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_13	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_14	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_14	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.12)	(1.00)	1.00	-	-
Cash flow 3 Event_14	-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(52.38)	-	-50.46	-	-	(0.36)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_14	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_15	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_15	(0.63)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.12)	(1.00)	1.00	-	-
Cash flow 3 Event_15	-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(52.38)	-	-50.46	-	-	(0.36)	3.00	(1.00)	-	(0.63)
Cash flow 4 Event_15	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(219.05)	-
Cash flow 1 Event_16	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_16	(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.12)	(1.00)	1.00	-	-
Cash flow 3 Event_16	-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(52.38)	-	-50.46	-	-	(0.36)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_16	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-

NonZero Dec Var 39 Constraints 108 No conting parm 4		Year 2 (Days) TempOff2	(Has) ForestCle	(Has) FallowMa	(Has) Maize2	(kg) MaizeSale	(kg) MaizeCons	(kg) MaizeBuy	(Has) Beans2	(kg) BeansSal	(kg) BeansCon	(kg) BeansBuy	(Has) Coffee2	(Has) Pasture2	(Has) RentPastu	(Days) HireLabor	(Days) Palma2	(Gruesas) PalmaSal	(US$) Credit2	(US$) Transfer2	(Adults) PermOff3	(Days) TempOff3
	58	0.0	0.0	2.9	1.5	0.0	1,840.0	368.0	0.7	0.0	598.0	0.0	0.0	0.0	0.0	0.0	442.5	3,582.2	200.0	0.0	0.0	0.0
Cash flow 2 Event_2		-0.63	48.46	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	10.32	-49.49	0.00	2.38	0.96	-0.24	-1.00	1.00	0.00	0.00
Cash flow 3 Event_2		0.00	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.01	0.00	0.00	-52.38	0.00	-50.46	0.00	0.00	-0.71	3.00	-1.00	0.00	-0.63
Cash flow 4 Event_2		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-219.05	0.00
Cash flow 1 Event_3		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 2 Event_3		-0.63	48.46	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	10.32	-49.49	0.00	2.38	0.96	-0.12	-1.00	1.00	0.00	0.00
Cash flow 3 Event_3		0.00	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.51	0.00	0.00	-52.38	0.00	-50.46	0.00	0.00	-0.36	3.00	-1.00	0.00	-0.63
Cash flow 4 Event_3		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-219.05	0.00
Cash flow 1 Event_4		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 2 Event_4		-0.63	48.46	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	10.32	-49.49	0.00	2.38	0.96	-0.12	-1.00	1.00	0.00	0.00
Cash flow 3 Event_4		0.00	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.01	0.00	0.00	-104.76	0.00	-50.46	0.00	0.00	-0.36	3.00	-1.00	0.00	-0.63
Cash flow 4 Event_4		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-219.05	0.00
Cash flow 1 Event_5		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_5		(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.24)	(1.00)	1.00	-	-
Cash flow 3 Event_5		-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(104.76)	-	-50.46	-	-	(0.71)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_5		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_6		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_6		(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.24)	(1.00)	1.00	-	-
Cash flow 3 Event_6		-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(52.38)	-	-50.46	-	-	(0.71)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_6		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_7		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_7		(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.12)	(1.00)	1.00	-	-
Cash flow 3 Event_7		-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(104.76)	-	-50.46	-	-	(0.36)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_7		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_8		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_8		(0.63)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.12)	(1.00)	1.00	-	-
Cash flow 3 Event_8		-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(104.76)	-	-50.46	-	-	(0.36)	3.00	(1.00)	-	(0.63)
Cash flow 4 Event_8		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(219.05)	-
Cash flow 1 Event_9		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_9		(0.63)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.24)	(1.00)	1.00	-	-
Cash flow 3 Event_9		-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(52.38)	-	-50.46	-	-	(0.71)	3.00	(1.00)	-	(0.63)
Cash flow 4 Event_9		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(219.05)	-
Cash flow 1 Event_10		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_10		(0.63)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.24)	(1.00)	1.00	-	-
Cash flow 3 Event_10		-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(104.76)	-	-50.46	-	-	(0.71)	3.00	(1.00)	-	(0.63)
Cash flow 4 Event_10		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(219.05)	-
Cash flow 1 Event_11		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_11		(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.24)	(1.00)	1.00	-	-
Cash flow 3 Event_11		-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(104.76)	-	-50.46	-	-	(0.71)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_11		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_12		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_12		(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.24)	(1.00)	1.00	-	-
Cash flow 3 Event_12		-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(52.38)	-	-50.46	-	-	(0.71)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_12		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_13		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_13		(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.12)	(1.00)	1.00	-	-
Cash flow 3 Event_13		-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(104.76)	-	-50.46	-	-	(0.36)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_13		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_14		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_14		(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.12)	(1.00)	1.00	-	-
Cash flow 3 Event_14		-	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(52.38)	-	-50.46	-	-	(0.36)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_14		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-
Cash flow 1 Event_15		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_15		(0.63)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.12)	(1.00)	1.00	-	-
Cash flow 3 Event_15		-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(52.38)	-	-50.46	-	-	(0.36)	3.00	(1.00)	-	(0.63)
Cash flow 4 Event_15		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(219.05)	-
Cash flow 1 Event_16		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-
Cash flow 2 Event_16		(0.16)	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	10.32	(49.49)	0.00	2.38	0.96	(0.12)	(1.00)	1.00	-	-
Cash flow 3 Event_16		-	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(52.38)	-	-50.46	-	-	(0.36)	3.00	(1.00)	-	(0.16)
Cash flow 4 Event_16		-	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(54.76)	-

NonZero Dec Var 39 Constraints 108 No conting parm 4	(Has) ForestClear	(Has) FallowMa	(Has) Maize3	(kg) MaizeSale	(kg) MaizeCons	(kg) MaizeBuy	(Has) Beans3	(kg) BeansSal	Year 3 (kg) BeansCon	(kg) BeansBuy	(Has) Coffee3	(Has) Pasture3	(Has) RentPastu	(Days) HireLabor	(Days) Palma3	(Gruesas) PalmaSal	(Kg) CattleSale	(US$) Credit3	(US$) LTCredit3	(US$) Transfer3	(US$) V1
58	0.0	0.0	0.0	0.0	1,840.0	1,840.0	0.7	0.0	598.0	0.0	0.0	0.0	1.5	18.4	573.2	4,640.5	0.0	0.0	62.5	0.0	0.0
Cash flow 2 Event_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 3 Event_2	48.46	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	0.00	-191.82	0.00	2.38	0.96	-0.24	0.00	-1.00	0.00	1.00	0.00
Cash flow 4 Event_2	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.01	0.00	0.00	-261.90	0.00	-50.46	0.00	0.00	-0.71	-0.71	3.00	27.00	-1.00	0.00
Cash flow 1 Event_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	1.00
Cash flow 2 Event_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 3 Event_3	48.46	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	0.00	-191.82	0.00	2.38	0.96	-0.12	0.00	-1.00	0.00	1.00	0.00
Cash flow 4 Event_3	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.51	0.00	0.00	-261.90	0.00	-50.46	0.00	0.00	-0.36	-0.71	3.00	27.00	-1.00	0.00
Cash flow 1 Event_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.00	0.00	1.00
Cash flow 2 Event_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cash flow 3 Event_4	48.46	0.00	3.20	0.00	0.00	0.13	11.90	0.00	0.00	0.51	0.00	-191.82	0.00	2.38	0.96	-0.12	0.00	-1.00	0.00	1.00	0.00
Cash flow 4 Event_4	0.00	0.00	0.00	-0.13	0.00	0.00	0.00	-0.01	0.00	0.00	-523.81	0.00	-50.46	0.00	0.00	-0.36	-0.71	3.00	27.00	-1.00	0.00
Cash flow 1 Event_5	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(1.00)	-	1.00
Cash flow 2 Event_5	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	
Cash flow 3 Event_5	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	-	(191.82)	0.00	2.38	0.96	(0.24)	-	(1.00)	-	1.00	
Cash flow 4 Event_5	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(523.81)	-	-50.46	-	-	(0.71)	(0.71)	3.00	27.00	(1.00)	
Cash flow 1 Event_6	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(1.00)	-	1.00
Cash flow 2 Event_6	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	
Cash flow 3 Event_6	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	-	(191.82)	0.00	2.38	0.96	(0.24)	-	(1.00)	-	1.00	
Cash flow 4 Event_6	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(261.90)	-	-50.46	-	-	(0.71)	(0.71)	3.00	27.00	(1.00)	
Cash flow 1 Event_7	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(1.00)	-	1.00
Cash flow 2 Event_7	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	
Cash flow 3 Event_7	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	-	(191.82)	0.00	2.38	0.96	(0.12)	-	(1.00)	-	1.00	
Cash flow 4 Event_7	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(523.81)	-	-50.46	-	-	(0.36)	(0.71)	3.00	27.00	(1.00)	
Cash flow 1 Event_8	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(1.00)	-	1.00
Cash flow 2 Event_8	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	
Cash flow 3 Event_8	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	-	(191.82)	0.00	2.38	0.96	(0.12)	-	(1.00)	-	1.00	
Cash flow 4 Event_8	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(523.81)	-	-50.46	-	-	(0.36)	(0.71)	3.00	27.00	(1.00)	
Cash flow 1 Event_9	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(1.00)	-	1.00
Cash flow 2 Event_9	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	
Cash flow 3 Event_9	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	-	(191.82)	0.00	2.38	0.96	(0.24)	-	(1.00)	-	1.00	
Cash flow 4 Event_9	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(261.90)	-	-50.46	-	-	(0.71)	(0.71)	3.00	27.00	(1.00)	
Cash flow 1 Event_10	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(1.00)	-	1.00
Cash flow 2 Event_10	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	
Cash flow 3 Event_10	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	-	(191.82)	0.00	2.38	0.96	(0.24)	-	(1.00)	-	1.00	
Cash flow 4 Event_10	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(523.81)	-	-50.46	-	-	(0.71)	(0.71)	3.00	27.00	(1.00)	
Cash flow 1 Event_11	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(1.00)	-	1.00
Cash flow 2 Event_11	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	
Cash flow 3 Event_11	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	-	(191.82)	0.00	2.38	0.96	(0.24)	-	(1.00)	-	1.00	
Cash flow 4 Event_11	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(523.81)	-	-50.46	-	-	(0.71)	(0.71)	3.00	27.00	(1.00)	
Cash flow 1 Event_12	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(1.00)	-	1.00
Cash flow 2 Event_12	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	
Cash flow 3 Event_12	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	-	(191.82)	0.00	2.38	0.96	(0.24)	-	(1.00)	-	1.00	
Cash flow 4 Event_12	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(261.90)	-	-50.46	-	-	(0.71)	(0.71)	3.00	27.00	(1.00)	
Cash flow 1 Event_13	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(1.00)	-	1.00
Cash flow 2 Event_13	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	
Cash flow 3 Event_13	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	-	(191.82)	0.00	2.38	0.96	(0.12)	-	(1.00)	-	1.00	
Cash flow 4 Event_13	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(523.81)	-	-50.46	-	-	(0.36)	(0.71)	3.00	27.00	(1.00)	
Cash flow 1 Event_14	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(1.00)	-	1.00
Cash flow 2 Event_14	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	
Cash flow 3 Event_14	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	-	(191.82)	0.00	2.38	0.96	(0.12)	-	(1.00)	-	1.00	
Cash flow 4 Event_14	-	-	-	(0.13)	-	-	-	(0.51)	-	-	(261.90)	-	-50.46	-	-	(0.36)	(0.71)	3.00	27.00	(1.00)	
Cash flow 1 Event_15	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(1.00)	-	1.00
Cash flow 2 Event_15	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	
Cash flow 3 Event_15	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	-	(191.82)	0.00	2.38	0.96	(0.12)	-	(1.00)	-	1.00	
Cash flow 4 Event_15	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(261.90)	-	-50.46	-	-	(0.36)	(0.71)	3.00	27.00	(1.00)	
Cash flow 1 Event_16	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	(1.00)	-	1.00
Cash flow 2 Event_16	-	-	-	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-	-	-	-	
Cash flow 3 Event_16	48.46	-	3.20	-	-	0.13	11.90	-	-	0.51	-	(191.82)	0.00	2.38	0.96	(0.12)	-	(1.00)	-	1.00	
Cash flow 4 Event_16	-	-	-	(0.13)	-	-	-	(0.01)	-	-	(261.90)	-	-50.46	-	-	(0.36)	(0.71)	3.00	27.00	(1.00)	

NonZero Dec Var 39 Constraints 108 No conting parm 4		(US$) V2	(US$) V3	(US$) minusD1	(US$) minusD2	(US$) minusD3	(US$) ExpTotMarg	Constraint	Relation	RHS
	58	0.0	385 2	948.8	948 8	563 7	2,091 2	0		
Cash flow 2 Event_2		1 00	0.00	0 00	0 00	0 00	0 00	(700 2)	≤	0
Cash flow 3 Event_2		0.00	1 00	0 00	0 00	0 00	0 00	(1,831 8)	≤	0
Cash flow 4 Event_2		0 00	0 00	0 00	0 00	0 00	0 00	(1,702 3)	≤	-45
Cash flow 1 Event_3		0 00	0 00	0 00	0 00	0 00	0 00	3 5	≤	45
Cash flow 2 Event_3		1 00	0 00	0 00	0 00	0 00	0 00	0 0	≤	0
Cash flow 3 Event_3		0 00	1 00	0 00	0 00	0 00	0 00	0 0	≤	0
Cash flow 4 Event_3		0 00	0 00	0 00	0 00	0 00	0 00	(45 0)	≤	-45
Cash flow 1 Event_4		0 00	0.00	0 00	0 00	0 00	0 00	3 5	≤	45
Cash flow 2 Event_4		1 00	0.00	0 00	0 00	0 00	0 00	0 0	≤	0
Cash flow 3 Event_4		0 00	1.00	0 00	0 00	0 00	0 00	0.0	≤	0
Cash flow 4 Event_4		0 00	0 00	0.00	0 00	0 00	0 00	(45 0)	≤	-45
Cash flow 1 Event_5								(46 2)	≤	45
Cash flow 2 Event_5		1.00						(700 2)	≤	0
Cash flow 3 Event_5			1 00					(1,831 8)	≤	0
Cash flow 4 Event_5								(1,702 3)	≤	-45
Cash flow 1 Event_6								(46 2)	≤	45
Cash flow 2 Event_6		1.00						(700 2)	≤	0
Cash flow 3 Event_6			1 00					(1,831 8)	≤	0
Cash flow 4 Event_6								(1,702 3)	≤	-45
Cash flow 1 Event_7								45 0	≤	45
Cash flow 2 Event_7		1 00						0 0	≤	0
Cash flow 3 Event_7			1.00					(0 0)	≤	0
Cash flow 4 Event_7								(45 0)	≤	-45
Cash flow 1 Event_8								3 5	≤	45
Cash flow 2 Event_8		1.00						0 0	≤	0
Cash flow 3 Event_8			1 00					(0 0)	≤	0
Cash flow 4 Event_8								(45 0)	≤	-45
Cash flow 1 Event_9								(87 7)	≤	45
Cash flow 2 Event_9		1.00						(700 2)	≤	0
Cash flow 3 Event_9			1.00					(1,831 8)	≤	0
Cash flow 4 Event_9								(1,702 3)	≤	-45
Cash flow 1 Event_10								(87 7)	≤	45
Cash flow 2 Event_10		1 00						(700 2)	≤	0
Cash flow 3 Event_10			1.00					(1,831 8)	≤	0
Cash flow 4 Event_10								(1,702 3)	≤	-45
Cash flow 1 Event_11								(46 2)	≤	45
Cash flow 2 Event_11		1 00						(700 2)	≤	0
Cash flow 3 Event_11			1 00					(1,831 8)	≤	0
Cash flow 4 Event_11								(1,702 3)	≤	-45
Cash flow 1 Event_12								(46 2)	≤	45
Cash flow 2 Event_12		1 00						(700 2)	≤	0
Cash flow 3 Event_12			1 00					(1,831 8)	≤	0
Cash flow 4 Event_12								(1,702 3)	≤	-45
Cash flow 1 Event_13								45 0	≤	45
Cash flow 2 Event_13		1 00						0 0	≤	0
Cash flow 3 Event_13			1.00					0 0	≤	0
Cash flow 4 Event_13								(45 0)	≤	-45
Cash flow 1 Event_14								45 0	<	45
Cash flow 2 Event_14		1 00						0 0	≤	0
Cash flow 3 Event_14			1 00					0 0	≤	0
Cash flow 4 Event_14								(45 0)	≤	-45
Cash flow 1 Event_15								3 5	≤	45
Cash flow 2 Event_15		1 00						0 0	≤	0
Cash flow 3 Event_15			1 00					0 0	≤	0
Cash flow 4 Event_15								(45 0)	<	-45
Cash flow 1 Event_16								45 0	≤	45
Cash flow 2 Event_16		1 00						0 0	≤	0
Cash flow 3 Event_16			1 00					0 0	≤	0
Cash flow 4 Event_16								(45 0)	≤	-45

6. Towards a strategy for land use management in the study area

6.1. Introduction

Designing policies for conservation and sustainable use of biodiversity and natural resources requires an understanding of the processes of resource use that are likely to prevail in the absence of those policies. Chapter 1 has discussed the conceptual and practical issues related to developing a framework for analyzing the process of biodiversity loss. Chapter 2 has proposed a diagrammatic analysis of the sequence of land use change observed in several developing countries. This chapter develops a model of land use and resource extraction for the study area (section 6.2) as a basis for the design of conservation and sustainable use policies (section 6.3). Issues related to the implementation and funding of those policies are also addressed (sections 6.3.5 and 6.3.6).

6.2. Aggregation of farm-level decisions over space and time

In Chapter 5 a linear programming approach was used, to forecast farm-level trends in land use and extraction of natural products (mainly *Chamedor* Palm) from wilderness areas. In this section, an analytical framework will be developed, to aggregate farm level decisions over the different zones of the study area and obtain region-wide projections of land use patterns and resource use.

The approach is to simulate changes over time in a selected number of key stocks and flows, based on the farm-level resource allocation and land use choices analyzed in the previous chapter. The model, which is constructed using the dynamic modeling software *Stella 5.0* for *Windows*, consists of three broad sectors: a) Households and Land Tenure, b) Land Use, and c) Off-site economy (see Figure 6-1).

In sector a), the processes are modeled, of formation of new households, and of allocation of land among existing and new households given tenure rules. Based on decisions taken in sector a), sector b) describes the processes of transition of land among different uses, as well as the extraction of natural resources from the wild. The off-site economy (sector c) is the market for goods produced in the study area, as well as for labor not employed in agricultural and harvesting activities.

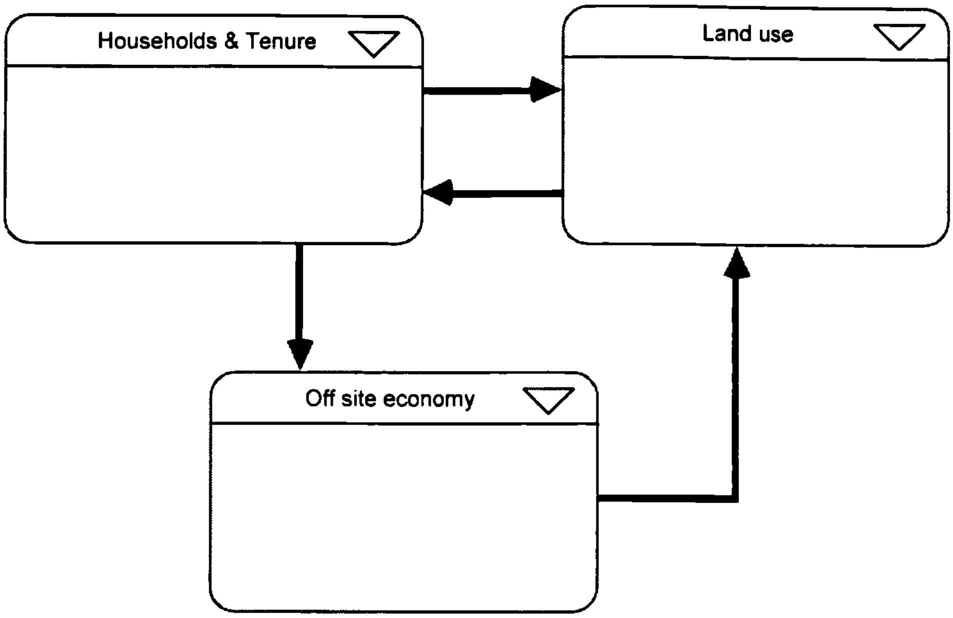


Figure 6-1: building blocks of the land use and resource extraction model

To improve realism, most of the variables and parameters included in the model are arrayed in one or both of two dimensions of variability. The first dimension refers to the Zoning and Administrative Units (ZAUs): there are seven of them, according to the categorization of chapter 4. The second dimension is the household type (HT): the model distinguishes among i) new households (who are assumed to have no land of their own), ii) existing households with no secure tenure, iii) existing households with secure tenure. Table 6-1 provides an illustration (with quantitative values for a selected number of variables) of the four possible combinations. The green, blue and yellow areas designate, respectively, quantities varying across HT and ZAUs, across ZAUs only, across HT only, and finally not varying across HT or ZAUs.

Table 6-1: Examples of arrayed variables

	Household types			No variation across Household type	
Zoning and administrative units (ZAUs)	New Households	Existing Households (no secure tenure)	Existing Households secure tenure)	Percentage encroachable space	Percentage households without secure tenure
Buffer Catemaco	Examples: Encroachers in "monte" and "acahual" areas; Households turned landless			20%	40%
Buffer Mecayapan				10%	13%
Buffer Soteapan				66%	24%
Influence Catemaco				20%	33%
Influence Mecayapan				10%	16%
Influence Pajapan				10%	11%
Influence Soteapan				66%	39%
	No variation across ZAUs:			No variation across ZAUs and Hhold types:	
Milpa size including fallow (Has)	5.1 (low employm.), 1 (high employm.)	10 (low employm.); 2 (high employm.)		Example:	
Palm Extraction (gruesas/ year)	3,000 (low employm.); 600 (high employm.)		200	Percentage of men in population	
Temp labor supply (days/ year)	30 (low employm.); 320 (high employm.)				

The model consists of a set of equations describing the relationships between stocks and flows. Stock/ flow relationships are also represented visually by diagrams, like the one of Figure 6-2 for the household sector. Each icon in diagrams like Figure 6-2 represents an equation[1], or the initial value of a variable. In the following sections, the structure of the model will be explained by presenting and discussing a set of key equations.

[1] Equations are reported directly in the format given by the *Stella* software: variable names are the same, descriptive ones, used in the diagramming layer of the software (the source of Figure 6-2). Because of their array nature, several variables are in the form ***Variable[Zone, Hhold_type]***; quantity appearing in square brackets are not arguments, but rather equivalents to subscripts denoting variation across dimensions. In more standard notation, the same expression would be $\boldsymbol{Variable_{ij}}$, meaning value of the *variable* for zone ***i*** and household type ***j***.

6.2.1. The household sector

At the beginning of the simulation (which is assumed to be the beginning of 1996, i.e. right after data collection was completed in the study area), there is a stock of "settlers", that is, households who have rightful or *de facto*[2] access to land. As time goes by, a stock of "space seekers" is generated; inflows to this stock are given by i) the process of new household formation , and ii) by the process of eviction of existing settlers with no formal title to land. Households flow out of the space seekers stock through seven different channels:

a) Migration
b) Land Purchase;
c) Encroachment in communal secondary forest (*acahual*) in the community of residence;
d) Encroachment in communal primary forest (*monte*) in the community of residence
e) Use of existing agricultural space via reduction on the average parcel size (*minifundio*);
f) Encroachment in primary forest areas outside the community of origin, and
g) Destitution.

Equation 6-1 summarizes, at the generic time t, the balance of flows to and from the space seekers stock.:

[2] See the discussion on "avencidados" of chapter 4.

*Space_Seekers[Zone,Hhold_type](t) = Space_Seekers[Zone,Hhold_type](t - dt) + (Hhold_formation[Zone,Hhold_type] + Eviction[Zone,Hhold_type] - Encroachers_Acahual[Zone,Hhold_type] - Minifundistas[Zone,Hhold_type] - Encroachers_Monte[Zone,Hhold_type] - Off_site_encroachers[Zone,Hhold_type] - Destitution[Zone,Hhold_type] - Land_Purchasers[Zone,Hhold_type] - Migration[Zone,Hhold_type]) * dt*

Equation 6-1

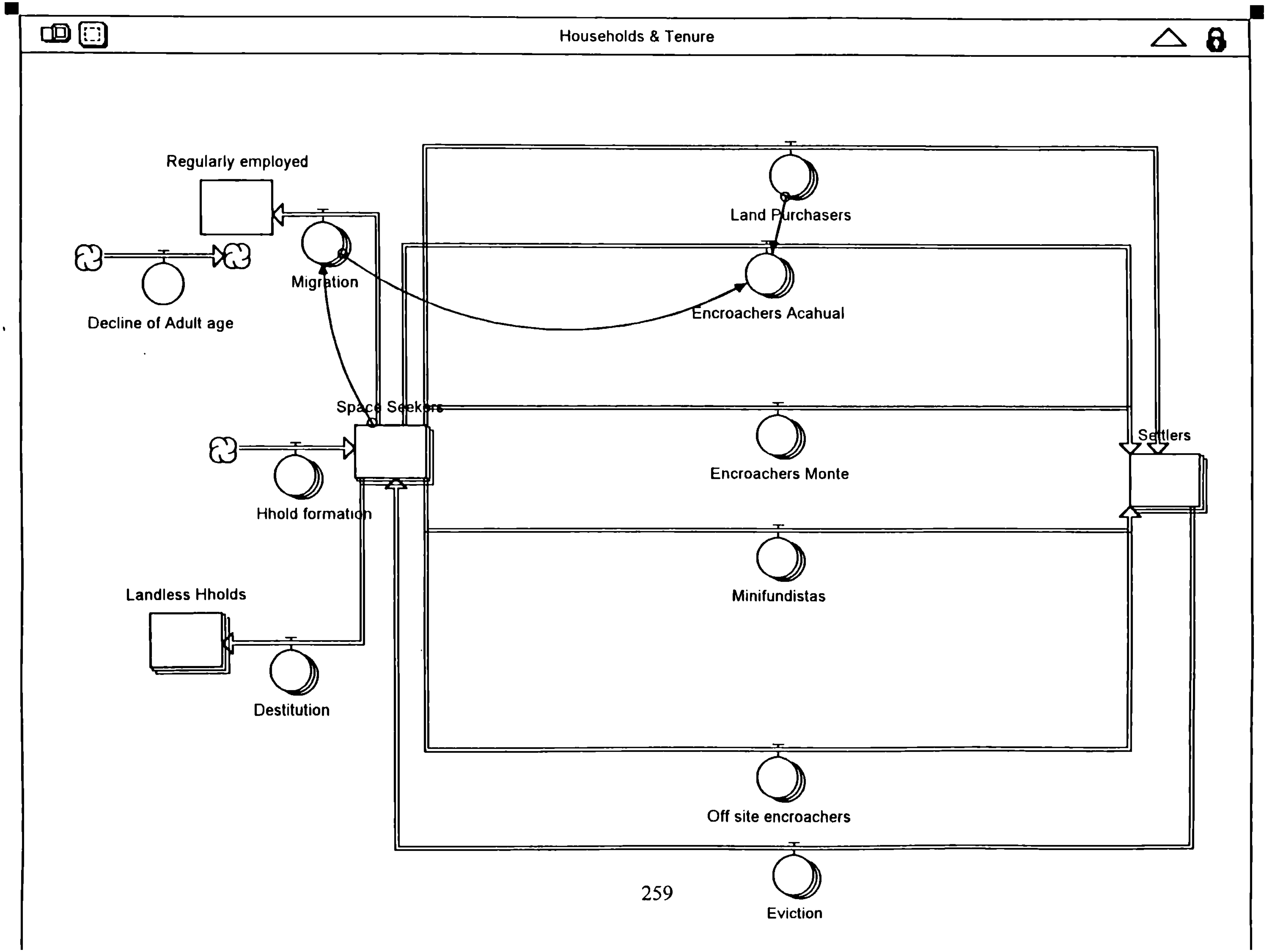
Outflows b) to f) entail increases in the ***Settlers*** stock; however, only outflows c), d) and f) entail land use changes:

*Settlers[Zone,Hhold_type](t) = Settlers[Zone,Hhold_type](t - dt) + (Encroachers_Acahual[Zone,Hhold_type] + Minifundistas[Zone,Hhold_type] + Encroachers_Monte[Zone,Hhold_type] + Off_site_encroachers[Zone,Hhold_type] + Land_Purchasers[Zone,Hhold_type] - Eviction[Zone,Hhold_type]) * dt*

Outflow a) increases the stock of permanent workers in the off-site economy, whereas outflow g) increases the stock of landless households:

*Landless_Hholds[Zone,Hhold_type](t) = Landless_Hholds[Zone,Hhold_type](t - dt) + (Destitution[Zone,Hhold_type]) * dt*

Let us look in some more detail at the determination of the flows to, and from, the ***Space Seekers*** and ***Settlers*** flows.


Households & Tenure
Regularly employed
Migration
Decline of Adult age
Land Purchasers
Encroachers Acahual
Space Seekers
Encroachers Monte
Settlers
Hhold formation
Minifundistas
Landless Hholds
Destitution
Off site encroachers
Eviction

6.2.1.1.Inflows to the Space Seekers stock

Formation of new households

As it was mentioned in chapter 5, it is assumed that a new household is formed every time a male individual reaches the adult age (18 years). To obtain estimates on the yearly numbers of new adults, the following procedure was used. Official data on the age structure of the male and female population was available for a subset of 17 communities of the Mecayapan and Soteapan municipalities (2 in the buffer and 15 in the influence zone).

Age classes were of one year intervals for the youngest ages (up to 15 years), and of wider (two to four years) intervals for the remaining classes. Through linear interpolation of the non-unit intervals, it was possible to construct a year-by-year cumulative age distribution function of the population. This distribution did not exhibit substantial variation over the subset of the 17 sampled communities.

An average of the percentage distribution of ages was therefore used, weighted by the size of the total (male and female) population relative to the total of the 17 units sample. The result is indicated by the function FDISTRIB(.) reported in Equation 6-2, which maps into number of new adults the flow of time, and the consequent decrease of the 1995 adult age (for example, individuals who were 16 years old in 1995 will be 18 in 1997, that is, in year 2 of the simulation)[3].

[3] In several of the equations specified in the model, "dummy" variables are used. These have in general the purpose of limiting to impact of given processes of change to selected components of arrayed variables. For

*Hhold_formation[Zone,Hhold_type] = Dummy_New_Hholds[Hhold_type] * People_per_Hhold[Zone] * (delay(Average_men_age_structure,1)-Average_men_age_structure) * INT(Proportion_of_men[Zone] * (INIT(Settlers[Zone,Existing_NoTitle]) + INIT(Settlers[Zone,Existing_Title])))*
Average_men_age_structure = FDISTRIB(Decline_of_Adult_age)

Equation 6-2

Figure 6-3 displays, in quality of example, the process of household formation in one of the seven ZAUs, the Influence zone in the Soteapan Municipality.

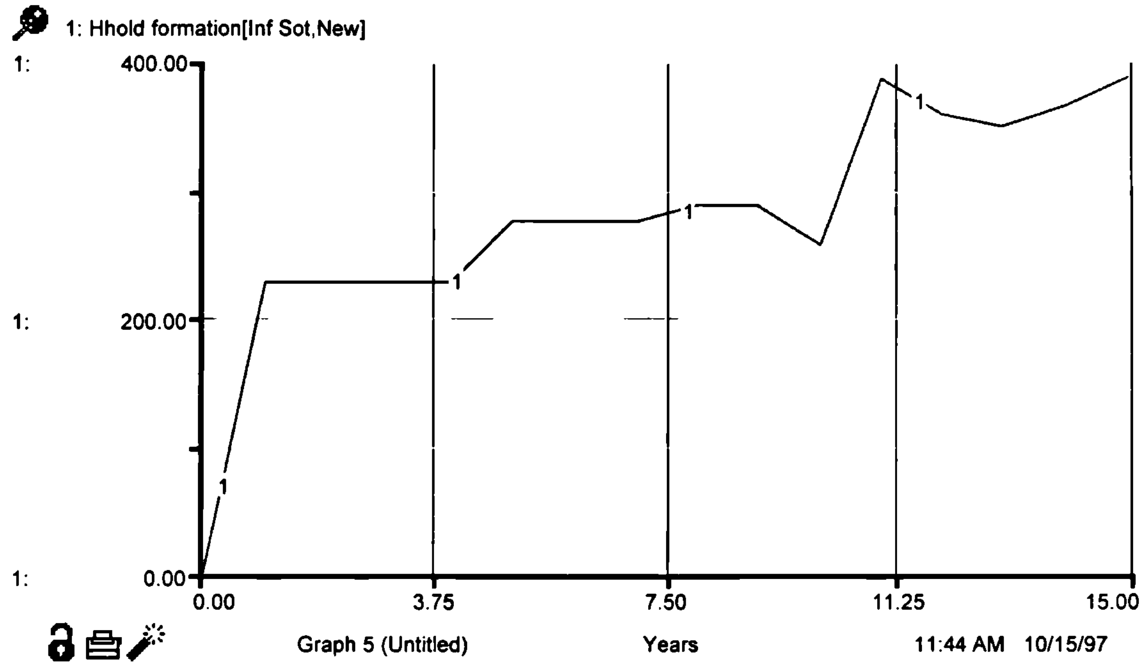


Figure 6-3: Formation of new households

Eviction

As discussed in chapters 4 and 5, application of PROCEDE, the land titling program currently under way in Mexico, is likely to result in eviction of farmers who are not in

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example, the quantity *Dummy_New_Hholds[Hhold_type]* in Equation 6-2, has the purpose of activating the household formation process only in the "New" component of the Household Type array.

possess of a valid *ejidatario* title and who do not own private land. Assuming that no mitigating measure will be in place, displaced farmers will be forced to join the pool of space seekers. The rate at which this will happen depends upon the implementation modalities of the land titling program. For simplicity, it will be assumed here that displacement of titleless farmer will be evenly distributed over the time horizon of the simulation, starting from the second year:

```
Eviction[Zone,Hhold_type] = IF(time<2) then 0 else Dummy_avencid[Hhold_type] *
INIT(Settlers[Zone,Hhold_type]) / (STOPTIME-1)
```

6.2.1.2. Outflows from the Space Seekers stock

Migration

In accordance with the evidence presented in chapter 4, some of the inhabitants of the study area tend to migrate to the municipalities of the oil district. Migration is assumed to depend on the demand for regular (i.e., non temporary) work in the oil district; this, in turn, is a function of the region's income, and will be modeled in section 6.2.2, which describes the off-site economy sector.

Land purchase

Some of the households forming the space seekers pool may in fact benefit from the revitalization of the land market which should follow the titling regularization process. Farmers with necessary resources may purchase land instead of encroaching into remaining communal areas. It is plausible that land purchases will be more likely among established households, who might have had more saving opportunities in the past than newly formed households. It is assumed that a fraction[4] of the evicted household will flow from the space seekers to the settlers stock through land purchases:

*Land_Purchasers[Zone,Hhold_type] = INT(Delay(Eviction[Zone,Existing_NoTitle], 1) * Percent_wealthy_avenc)*

Searching land for subsistence farming

The linear programming model of chapter 5 provided indications on the size of the agricultural area which will be needed by new and evicted households pursuing survival strategies, with no access to land of their own. As discussed in that chapter, the size of the area converted depends on a number of factors, including access to credit, family size and employment prospects. The last two are explicitly included in this model: family size varies across household types, and the determination of the employment probability is included in the off-site economy sector of the model, as explained below (section 6.2.2).

The impact on land use (and thus ecosystem condition) depends on the way the demand for land of space seekers will be met. This, in turn, depends on a) the land use and conversion options available, b) the relative attractiveness of the various options, and c), given constraints on the overall area of the different land types, the way in which a given land use option will be adjudicated to different household types competing for it.

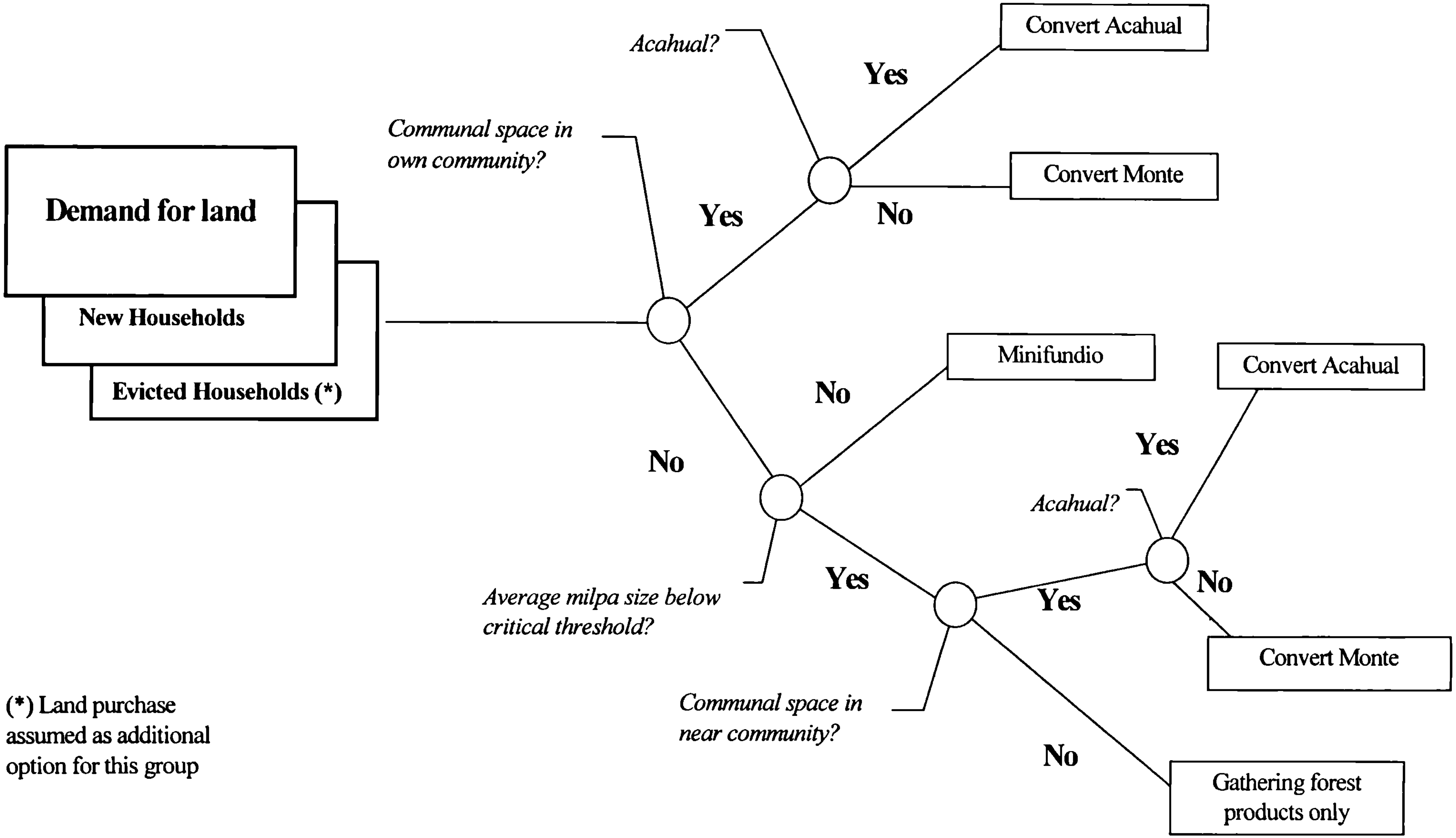
Based on the existing literature (Pare et al., 1993) on field observations, and on a priori judgment, this model proposes a conceptual framework addressing these three issues. This is summarized by the decision tree depicted in Figure 6-4.

[4] Based on survey information, this fraction is estimated at 15%.

Both types of space seekers, newly formed and evicted households, will be faced with a number of options to meet their demand for land[5]. This model assumes that both groups will follow the same decision path, which dictates the land use options chosen at each of six decision nodes illustrated in Figure 6-4, as a function of the "state of nature" prevailing at that node. When land of a given type is not sufficient to meet the demand of the entire space seekers group, it is assumed that evicted farmers will have priority over new households. Given that evicted farmers have by definition more "seniority of residence" in the community, this may not be an implausible assumption[6].

[5] In their study of deforestation in Mexico, (Barbier & Burgess, 1996) observe that a critical determinant of deforestation is the choice of whether to increase production in land already converted (previously cultivated and currently idle), or in "frontier" land. They argue that much of the forest loss is due to the fact that policies have been inducing farmers to prefer the second to the first option. In the present model, the choice of "frontier land" is not directly affected by policies, but is a result of the "space seekers" not having access to credit, and hence to land, markets.

[6] Note that this is not necessarily a "space-efficient" allocation rule. A more efficient rule may be to allocate land across different user groups in a way that minimizes the total space requirement of those who have to be excluded from the allocation.



(*) Land purchase assumed as additional option for this group

Figure 6-4: decision tree for land conversion and use

Let us now elaborate on the various steps of the assumed sequential decision making process. The first option will be use of encroachable spaces[7] to establish *milpa*-type subsistence agriculture.

Because of lower cost, conversion of communal second growth (*acahual*) vegetation will be preferred to conversion of primary forest (*monte*), which it is assumed will start only upon complete conversion of the first type of land. The number of households encroaching into *acahual* areas will be:

```
Encroachers_Acahual[Zone,Hhold_type] = IF(Encroachable_Acahual[Zone]>
(Space_Seekers[Zone,New] * Milpa_size[New] + Space_Seekers[Zone,Existing_NoTitle] +
Milpa_size[Existing_NoTitle]))
THEN
INT(Dummy_non_settled[Hhold_type] * Space_Seekers[Zone,Hhold_type]) ELSE
Dummy_avencid[Hhold_type] * Int(Encroachable_Acahual[Zone]/Milpa_size[Existing_NoTitle])
```

At any given time and in any given zoning unit, if space allows it[8], all space seekers will settle in remaining encroachable *acahual*. Otherwise, the above mentioned rule will apply, which benefits evicted households: only a certain number of evicted farmers will encroach in *acahual* areas. This number is given by the encroachable land under second growth divided by the per-household farm area, as calculated in the evicted farmers LP model of chapter 5.

---

[7] Encroachment is likely to take place in land which has not yet been parceled, as well as in private or parceled land where topographical conditions make monitoring difficult. The percentages of encroachable land for the various zoning and administrative units of the region used in the present analysis are based on the survey evidence on the communal land parceling process, which was discussed in chapter 4 and summarized in Table 6-1.

[8] In each ZAU, total space needed for *milpa* use is given by the dot product of space seekers times *milpa* size across the different household types.

Space seekers who don't manage to settle down in *acahual* land (*Non_acahual_encr*) are likely to follow the next option in the decision tree of Figure 6-4, that is conversion of *monte* areas:

```
Encroachers_Monte[Zone,Hhold_type] = IF(Encroachable_Monte[Zone] >
(Non_acahual_encr[Zone,New] * Milpa_size[New] + Non_acahual_encr[Zone,Existing_NoTitle] *
Milpa_size[Existing_NoTitle] + Non_acahual_encr[Zone,Existing_Title] *
Milpa_size[Existing_Title]))
THEN Non_acahual_encr[Zone,Hhold_type]
ELSE Dummy_avencid[Hhold_type] *
INT(Encroachable_Monte[Zone]/Milpa_size[Existing_NoTitle])
```

The number of encroachers in primary forest will be equal to the number of non-*acahual* encroachers, if there is sufficient communal *monte* area; otherwise, much as in the case of encroachment in second growth areas, priority will be given to evicted farmers.

Sharing farm land with existing household ("minifundio")

Field observations suggest that in communities with little remaining encroachable land, households in search of areas for farming tend to establish themselves in spaces already under agricultural production, which is rented (often against payment in kind of labor or crops) or borrowed from friends and relatives. This process, known locally as *Minifundio*, entails an increase in settlement density, and correspondingly a decrease in the average parcel size. The *Minifundio* is a short-term response to land scarcity, based on family and community-based exchange and support mechanisms; the *Minifundio* is unlikely to be sustainable in the medium to long term unless improvements in fertility conservation techniques prevent the decreases of yields per hectare eventually resulting from smaller crop areas and shorter fallow periods[9].

It is assumed that in communities where the average *milpa* size has dropped to critical thresholds[10], *minifundio* will no longer be a settlement option. Otherwise, all space seekers who did not manage to encroach in communal forest (primary or second growth), will turn into "minifundistas".

Minifundistas[Zone,Hhold_type] = IF(Non_monte_encr[Zone,Hhold_type] = 0) THEN 0 *ELSE IF(Avg_Milpa_Size[Zone] < Minimum_Milpa_Size)* *THEN 0 ELSE Non_monte_encr[Zone,Hhold_type]*

Encroachment in communal land outside the community of origin

In cases where encroachment in communal areas is not possible and settlement density is too high, space seekers may turn to other nearby communities to meet their demand for land. Precise modeling of inter-community migration would require a great deal of information on resettlement and transport costs, patterns of relative land fertility and so forth. In the present context, it is assumed that a) space seekers coming from land units with a land deficit will be evenly distributed across land units with remaining land availability; b) outsiders will only encroach in *monte* areas; and c) land sharing (*minifundio)* outside of the community of origin will not take place (it is likely that kin-based support mechanisms will be less common outside the community of origin).

[9] See (Buckles & Erenstein, 1996) for a discussion of causes of, and remedies to, the declining productivity of maize-based systems in the region.

[10] For heuristic purposes, the numerical value of this minimum average *milpa* size threshold has been set at 2 has.

```
Off_site_encroachers[Zone,Hhold_type] = IF(Non_minifund[Zone,Hhold_type] =0) THEN 0
ELSE IF(Non_minifund[Zone,New] * Milpa_size[New] + Non_minifund[Zone,Existing_NoTitle] *
Milpa_size[Existing_NoTitle] + Non_minifund[Zone,Existing_Title] * Milpa_size[Existing_Title])<
Total_encr_monte
THEN Non_minifund[Zone,Hhold_type]
ELSE Dummy_avencid[Hhold_type] * INT(Total_encr_monte/Milpa_size[Existing_NoTitle])
```

The demand for encroachment outside the community of residence is given by all those households that have not been able to settle down as minifundistas (and, by implication, who were not able to encroach in communal forested areas). The supply of potential settlement space will be given by the sum of remaining encroachable *monte* areas in all the ZAUs of the study area. If that area is smaller than the dot product of non-minifundistas, times *milpa* sizes, across the different household types, only evicted farmers will be able to encroach in primary forest located outside the community of origin.

Landless households

Where no settlement options is available, households will flow out of the space seekers pool and will add to the stock of landless farmers[11]. These destitute households will only be able to support themselves through temporary employment, and through extraction of natural products from forested areas in the buffer and nucleus zone.

```
Marginalization[Zone,Hhold_type] = Non_minifund[Zone,Hhold_type] -
Off_site_encroachers[Zone,Hhold_type]
```

[11] Initial values for this stock are taken from table 4-10, column "totally landless".

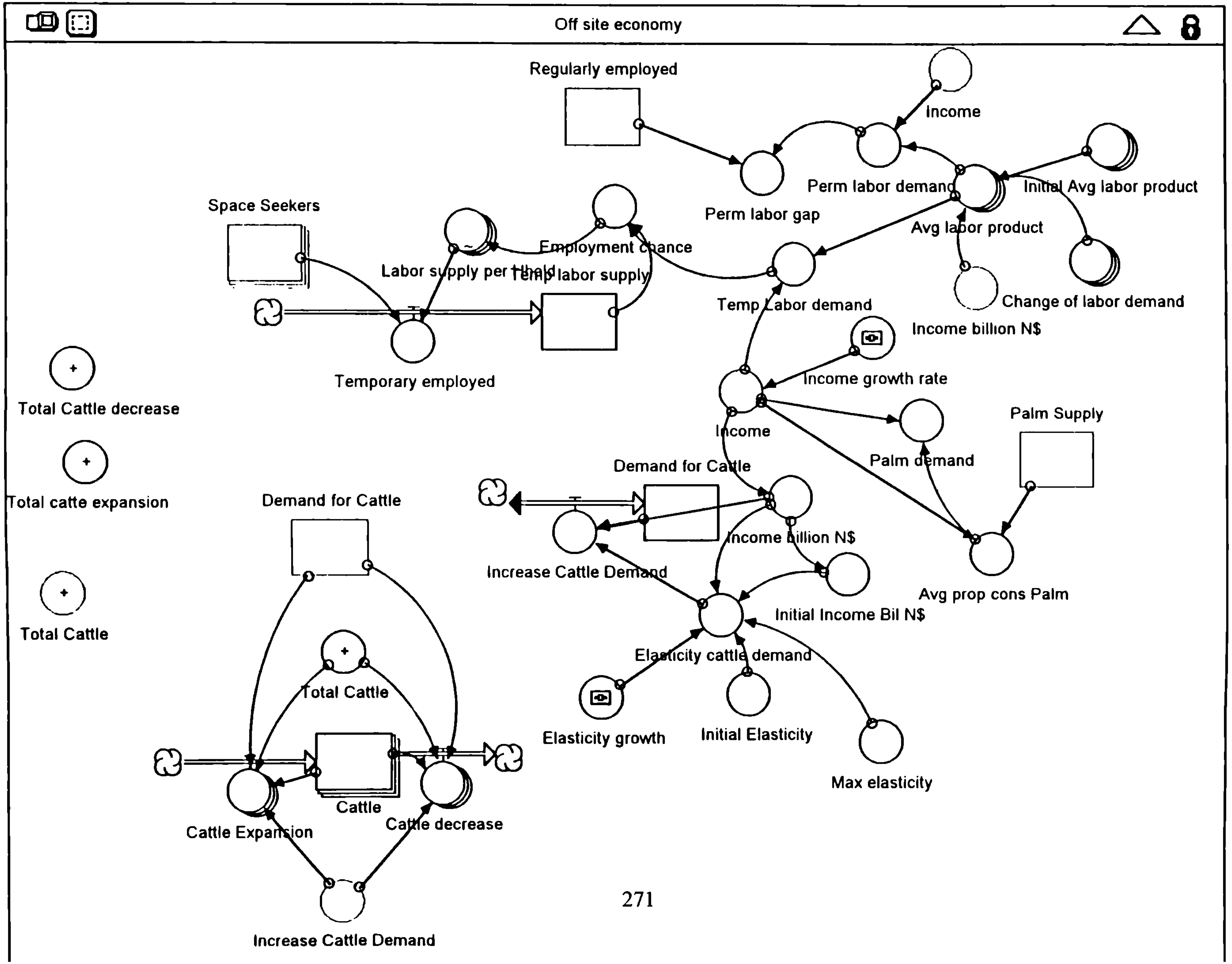
6.2.2. The off-site economy sector

This sector is the market for goods and services not exchanged within the household sector, bur rather supplied for external purchase or hiring. In this model there are three main types of transaction between the rural household sector and the rest of the region's economy: a) the sale of forest products (Chamedor Palm) b) the sale of livestock products (milk and beef), and c) and the supply of labour.

However, in order to concentrate the subsequent policy analysis on a limited number of key parameters, the attention will be focused on the last two variables (livestock and labor supply), leaving aside explicit modeling of the Chamedor Palm market[12].

The off-site economy sector is the "gate" through which the national and global economies affect productive activities and natural resource use in the Sierra. As it will be discussed in this section, aggregate production and income in the southern Gulf of Mexico oil district are assumed to determine the demand for products and serviced exported by the Sierra. Output in the oil district is clearly responsive to the overall volume of activity of Mexico's economy, which in turn, in a context of growing integration in the global markets, is affected by the world economy. Based on the objective this research, the linkages between regional, national and global economy, albeit important, will not be addressed here.

[12] Constant farmgate prices for Palm will be assumed, on the grounds that a) most of the sales are for exports outside the region, and in part outside the country, so that regional policy makers are unlikely to be able to exercise control on Palm's price; b) the Sierra is a small producer, and hence unable to affect Palm prices.


Off site economy
Regularly employed
Income
Perm labor demand
Initial Avg labor product
Perm labor gap
Avg labor product
Space Seekers
Employment chance
Labor supply per Hhold
Temp labor supply
Change of labor demand
Temp Labor demand
Income billion N$
Temporary employed
Income growth rate
Total Cattle decrease
Income
Palm Supply
Palm demand
Total catte expansion
Demand for Cattle
Demand for Cattle
Income billion N$
Increase Cattle Demand
Avg prop cons Palm
Initial Income Bil N$
Total Cattle
Elasticity cattle demand
Total Cattle
Elasticity growth
Initial Elasticity
Max elasticity
Cattle
Cattle decrease
Cattle Expansion
Increase Cattle Demand

6.2.2.1. Labour markets

Labor market modeling will be by necessity simple, given the fact that the main emphasis of this research is on the rural sector, and that during field work it was possible to collect only a limited amount of information on the urban sector's labour market.

As discussed in chapter 4, households of the study area may supply labor to the off-site economy in two ways: permanent migration and temporary employment. Equilibrium in both markets is achieved through adjustments in the quantities supplied; wages are assumed constant and equal to the marginal products of labor. Let us look at the way demands for temporary and regular labor are determined.

The starting point is the assumption of a simple production function for the aggregate output of the trade, manufacture, mining and services industries, whereby production is a function of regular labour, non-regular or unskilled labour, and capital:

$$Y = f(L^R, L^{NR}, K)$$

Equation 6-3

Data on 1994 employment of regular and non-regular labour and on value of aggregate production was obtained from the Economic Census for that year (INEGI, 1994; INEGI, 1997). The data is available at the municipio level of aggregation; so that information was collected on the four municipalities which provide most of employment opportunities in the region: Acayucan, Coatzacoalcos, Cosoleacaque, and Minatitlan.

For each labour type (regular, non regular), the ratio, y_L , between the value of production ***Y***, and labour input, ***L***, gives the average value of product of that labour type: $y_L = Y/L$. At any point in time the demand for each labour type is simply the product of the value of output times the reciprocal of the average value product of labour. For example, assuming a simple exponential growth of income, demand for labour at time ***t*** is (***r*** is income's growth rate)

$$L_t = \frac{Y_0 e^{rt}}{y_t^L}$$

Equation 6-4

The actual value of the demand for labor depends on the assumed behavior of the average (value) product of labour, which in turn depends on assumptions on technical progress. Assumption on technical progress are important in the context of the present study area: the various reorganization plans (see discussion in chapter 4) being formulated for the oil district suggest that labor intensity of production in a number of firms of the manufacture and service sectors may decrease, with important consequences for overall employment patterns in the region.

With no technical progress, the average product of labor stays the same, which amounts to dropping the time subscript in Equation 6-4: labor demand always grows (and at a constant rate) when production grows. With technical progress that substitutes the selected labor type with other inputs, the correspondence between increase in production and increase in labor hiring no longer always holds.

One simple way of describing the impact of technical progress on the demand for labor is to express the average (value) product as an exponential function of production increase:

$$y_t^L = y_0^L e^{\rho (Y - Y_0)}$$

Equation 6-5

where y_0^L is the initial value of the average value product of labor, Y_0 is the initial level of income, and ρ is a rate of growth parameter. If $\rho=0$, there is no technical progress, and the average product of labor is constant along the production's expansion path. If $\rho>0$, the average product of labor for given level of output increases with production. Whether the actual demand for labor will in fact increase depends on whether the "income" effect associated to the increase in production prevails over the "substitution" effect (less labor necessary per any level of output). The two possibilities are addressed in the model's simulation through appropriate choice of the technical change parameters in a scenario analysis (see section 6.2.4).

Initial values of the demand for labor and average labor product are obtained from INEGI data, as explained in detail in Annex 6-1. The equations for the demand for labor are thus:

Perm_labor_demand = Income/ Avg_labor_product[Perm]
Temp_Labor_demand = Income/ Avg_labor_product[Temp]

The equation(s) for the average value product of labor (which reiterates Equation 6-5) is:

*Avg_labor_product[Labor_type] = Initial_Avg_labor_product[Labor_type] * Exp(Change_of_labor_demand[Labor_type] * (Income_billion_N$ - INIT(Income_billion_N$)))*

So much for the demand for labor; let us now turn to the determination of the equilibrium quantities in the two segments of the labor market.

Temporary employment. The model of the previous chapter predicted that a given portion of the total household's time will be supplied in the labor market of the urban sector for temporary employment. The actual amount of household's labor supplied will respond to the perceived probability of finding employment.

This probability, in turn, will also affect household's decisions concerning agricultural land and natural product extraction: the subsistence constraint will be met by a combination, on the one hand, of use of natural resources obtained from the wild and from agriculture, and, on the other hand, of cash income earned through temporary employment. Higher employment chances will decrease farm land size and natural products extraction.

It is assumed that the probability of finding temporary employment is simply the ratio between the demand and the supply for temporary labour[13]:

Employment_chance = Labor_demand/Max(Temp_labor_supply, Labor_demand)

The initial stock of temporary workers is increased by the process of temporary job search:

*Temp_labor_supply(t) = Temp_labor_supply(t - dt) + (Temp_job_search) * dt*

[13] In order for this ratio not to exceed one, the actual expression used in the model is:
probability of empl = l_d / Max (l_d, l_s), where the subscripts refer to labor demand and supply, respectively.

The total temporary job seekers' flow depends on size of the space seekers pool, as well as on the labor supplied by each household. At any time, labour supply decisions are taken on the basis of the previous period's value of the employment chance (which is expected to prevail in the current working season):

Labor_supply_per_Hhold[Hhold_type] = Delay(Employment_chance, 1)

Total supply of temporary labour is given by the dot product of per household labour supply times the total number of households of various types in the different ZAUs:

Temp_job_search = ARRAYSUM(Space_Seekers[,New]) * Labor_supply_per_Hhold[New] + ARRAYSUM(Space_Seekers[*,Existing_NoTitle]) * Labor_supply_per_Hhold[Existing_NoTitle] + ARRAYSUM(Space_Seekers[*,Existing_Title]) * Labor_supply_per_Hhold[Existing_Title]*

Migration and regular employment.

In this model, migration simply responds to excess demand for regular labor. Given a "labor gap" between the demand for permanent labor and the stock of regularly employed workers:

Perm_labor_gap = Perm_labor_demand - Regularly_employed

total migration will cover the employment gap; the distribution of migration across the different ZAUs will be proportional to each ZAU's share in the total space seekers pool:

*Migration[Zone,Hhold_type] = INT(Perm_labor_gap * Space_Seekers[Zone,Hhold_type] /Max(1, Total_space_seekers))*

6.2.2.2. Demand for livestock products

As discussed in the literature (Toledo, 1992; Barbier & Burgess, 1996), the expansion of cattle ranching activities depend on a variety of factors, including local, national and international demand for meat and dairy products, relative prices, public policies, availability of suitable pasture land.

In the study area, as previous chapters have pointed out, livestock development, widely encouraged by proactive public policies, has been one of the main driving forces of social change and natural habitat modification in the region. Most of the public programs supporting cattle ranching have been discontinued in recent years; the future of ranching in the region is therefore likely to depend mainly on relative output and input prices, and patterns of demand.

On the unit margin front, prospects may improve because of the devaluation -induced increased competitiveness of the region's low-inputs ranching system. More uncertainty is associated to the evolution of demand in presence of stagnating or falling production (and hence income) in Mexico's economy, and in particular in Veracruz oil district. The present analysis therefore focuses on the impact of income (via demand for livestock products) on cattle ranching activities.

It is assumed that cattle herds adjust to variation in demand for livestock products[14]. In the absence of detailed information on the demand for individual products (milk, meat from various beef types, etc.), we have to use the number of heads of cattle as the actual dependent variable in the demand function. This may not be an implausible first order

[14] As discussed in chapter 5 (end of section 5.4.4), the adjustment in cattle numbers and thus pasture (the latter is addressed in section 6.2.3.2) follows a short-term increase in price of livestock products caused, for given herd sizes, by higher demand.

approximation: if the demand for meat or milk increases, there will need to be more animals to be milked or slaughtered.

Given the nature of the data collected during the field work of this research, it was not possible to estimate the demand for cattle numbers directly. Rather, it was assumed that, based on an underlying demand function C=f(P, Y), cattle number adjust to changes in income via an elasticity coefficient. An initial value for this coefficient was borrowed from the Mexico study of Barbier and Burgess (Barbier & Burgess, 1996). Based on cross-country regressions estimated on state-level data, these authors find that a 1% percent increase in income generates a 0.09% increase in cattle numbers[15]. At the beginning of the simulation, there is a stock of cattle in the study area, which reflects previous patterns of demand for livestock products. Increase in demand for cattle in excess of the existing stock are given by the livestock demand's income elasticity, times the increase in income:

Increase_Cattle_Demand = INT(Elasticity_cattle_demand DERIVN(Income_billion_N$, 1) * Demand_for_Cattle/ Income_billion_N$)*

When the demand for cattle numbers increases, herds sizes in the different ZAUs are adjusted in proportion to their relative share in the regions' total herd size.

*Cattle_Expansion[Zone] = IF(Increase_Cattle_Demand >0) THEN INT((Demand_for_Cattle-Total_Cattle) * Cattle[Zone]/Total_Cattle) ELSE 0*

[15] However, it is plausible that, as income grows, the weight of meat consumption in the average diet increases. If this is the case, the income elasticity of cattle numbers will not be constant, but rather positively correlated with income. As explained in Annex 6-2, the model assumes a logistic growth of the elasticity of cattle numbers, from an initial to a ceiling level.

6.2.3. The land use sector

This sector of the model studies the variation over time of a selected number of stocks of land uses: primary forest or *monte*, secondary forest or *acahual*, farm land or *milpa*, and pasture. In addition, it also examines the impact of human activities on the stock of a resource extracted from forested areas, Chamedor Palm. As visualized in Figure 6-6, conversion and/or regeneration flows link the various stocks. For example, forest conversion determines the decrease of the *monte* or *acahual* stocks, as well as the corresponding increase of the *milpa* or pasture stocks; conversely, regeneration flows determine increases in the stock of *acahual* at the expenses of pasture land.

6.2.3.1. Land conversion to agriculture

Based on the number of encroachers determined in the land tenure sector of the model, in any given zone conversion of *acahual* to *milpa* is given by:

*Conversion_Acahual_to_Milpa[Zone] = IF(Encroachable_Acahual[Zone]>0) THEN (Encroachers_Acahual[Zone,New] * Milpa_size[New] + Encroachers_Acahual[Zone,Existing_NoTitle] * Milpa_size[Existing_NoTitle] + Encroachers_Acahual[Zone,Existing_Title] * Milpa_size[Existing_Title]) ELSE 0*

That is, subject to space availability, conversion is equal to the dot product of the number of encroachers times the size of *milpa* area (as determined by Chapter's 5 model) across the different household types. The same dot product applies to the conversion of primary forest to farm areas, which, as indicated in the tenure sector of the model, does not start before all encroachable areas under secondary vegetation have been cleared:

*Conversion_Monte_to_Milpa[Zone] = Encroachers_Monte[Zone,New] * Milpa_size[New] + Encroachers_Monte[Zone,Existing_NoTitle] * Milpa_size[Existing_NoTitle] + Encroachers_Monte[Zone,Existing_Title] * Milpa_size[Existing_Title]*

In addition to conversion carried out by community residents, primary forest areas may also be cleared by space seekers coming from other communities:

*Off_site_monte_conversion[Zone] = IF(Encroachable_Monte[Zone] - Conversion_Monte_to_Milpa[Zone] > ARRAYSUM(Milpa_needed_off_site[*]) * Perc_tot_encr_monte[Zone]) THEN ARRAYSUM(Milpa_needed_off_site[*]) * Perc_tot_encr_monte[Zone] ELSE 0*

Equation 6-6

Equation 6-6 indicates that in any community, provided that even after local encroachment, there are still areas of primary forest available for outsiders, total demand for off-site *milpa* will translate into conversion in proportion to the community's share of total remaining forest. Demand for off-site *milpa*, in turn, will again be given by the dot product of off site encroachers times the size of *milpa* area across the different household types:

*Milpa_needed_off_site[Zone] = Off_site_encroachers[Zone,New] * Milpa_size[New] + Off_site_encroachers[Zone,Existing_NoTitle] * Milpa_size[Existing_NoTitle] + Off_site_encroachers[Zone,Existing_Title] * Milpa_size[Existing_Title]*

6.2.3.2.Pasture

Pasture is the largest use of land in the study area. Historical and current processes of land conversion to pasture are the result of a complex interplay of policy, tenure, social and technology factors, some of which have been studied in detail elsewhere in the literature on the region (Buckles, 1987; Chevallier & Buckles, 1995) (Lazos, 1995). The analysis of the process provided by the rest of this subsection (and complemented by Annex 6-3) is a simplified one.

The analysis of chapter 5 indicated that households without tenure are unlikely to convert communal forested land for pasture; therefore, the present model focuses on ranches already established in private land. Inflows to the Pasture stock come from (young and mature) *Acahual* lands, and both on-site and off-site conversion of *Monte*; outflows are related to the process of pasture abandonment.

*Pasture[Zone,Land_Type](t) = Pasture[Zone,Land_Type](t - dt)+ (Conversion_acahual_to_pasture[Zone,Land_Type] + Conversion_Monte_to_Pasture[Zone,Land_Type] + Conversion_off_site_monte_pasture[Zone,Land_Type] + Conversion_Young_Acahual_pasture[Zone,Land_Type] - Pasture_abandoning[Zone,Land_Type]) *dt*

Conversion of land from other uses to pasture may take place either to support a fixed herd when overgrazing leads to declining productivity in existing grazing lands, or to enable herd expansion. This model addresses both sources of demand for additional pasture land. At any point in time, conversion to pasture is given by the sum of pasture to be replenished following abandonment of overgrazed land, and of new pasture required to meet increase in the demand for cattle numbers (determined, as explained in section 6.2.2, in the off-site economy sector):

*Demand_for_pasture[Zone,Land_Type] = Dummy_Private_space[Land_Type] * ((1 - Percent_Undergrazed[Zone,Land_Type]) * Cattle_Expansion[Zone] / SR_Max[Zone,Land_Type] + Pasture_abandoning[Zone,Land_Type])*

Equation 6-7

Equation 6-7 says that not all of the increased demand for cattle is met by pasture increase. In undergrazed lands, herds increase by simply increasing the stocking rate (heads of cattle per hectare)[16]. Conversely, in overgrazed areas, conversion to pasture will be given by the ZAU's share in herd expansion divided by the going stocking rate[17]. The first option for meeting the demand for pasture is conversion of young *Acahual*. In particular, there will be a fraction of young *Acahual* that is converted to pasture:

Conversion_Young_Acahual_pasture[Zone,Land_Type] = LEAKAGE OUTFLOW; LEAKAGE FRACTION = Min(1, (Demand_for_pasture[Zone,Land_Type]/Max(1, Young_Acahual[Zone,Land_Type])))

[16] The division of pasture in over- and undergrazed land, and the process of regeneration of young and mature *Acahual* are both explained in Annex 6-3.

[17] The stocking rate used for determining conversion is the maximum, over a range of possible values prevailing in each ZAU: newly converted land are likely to be initially rich in nutrient, and thus able to support relatively large number of animals. Additional details on the estimation of stocking rate ranges are provided in Annex 6-3.

The fraction is given by the ratio between the demand for pasture and the stock of Young *Acahual*, if this is less than one; if the fraction is larger than one, then all the existing stock will be converted to pasture, and the difference will be made up for by the existing mature acahual:

Conversion_acahual_to_pasture[Zone,Land_Type] = IF(Acahual[Zone,Private]>0) then (Demand_for_pasture[Zone,Land_Type] - Conversion_Young_Acahual_pasture[Zone,Land_Type]) else 0

If the demand for replenishment or new pasture can not be met by conversion of *acahual* areas, conversion of primary forest takes place:

Conversion_Monte_to_Pasture[Zone,Land_Type] = Demand_for_pasture[Zone,Land_Type] - (Conversion_acahual_to_pasture[Zone,Land_Type] + Conversion_Young_Acahual_pasture[Zone,Land_Type])

If there is still an excess demand because all accessible land has been cleared in communities with herds in excess of going stocking rates, the deficit may be met by converting forested land in neighboring communities, and renting the resulting pasture to the ranchers of the deforested communities. Conversion in communities with remaining forest will take place by distributing the pasture deficit in proportion to the community's share in total monte:

*Conversion_off_site_monte_pasture[Zone,Land_Type] = Dummy_Private_space[Land_Type] * ARRAYSUM(Pasture_deficit[*,Private]) * Monte[Zone,Private]/(Max(1,Total_private_Monte))*

6.2.3.3. Forest extraction

Based on the evidence presented in chapter 4, settlers in the various zoning units are likely to extract a variety of products from forested areas. Much as in chapter 5, only *Chamedor* Palm's extraction will be modeled here.

On the basis of the recorded altitudinal distribution of extracted species, Palm populations are likely to be found in parts of the total area under primary forest in the core and buffer zones (approximately 50% of it). Accretions to the stock of Palm are given by the process of generation. For simplicity, a simple logistic growth process is assumed here, whereby the stock grows at a given rate per annum, up to the attainment of the habitat carrying's capacity.

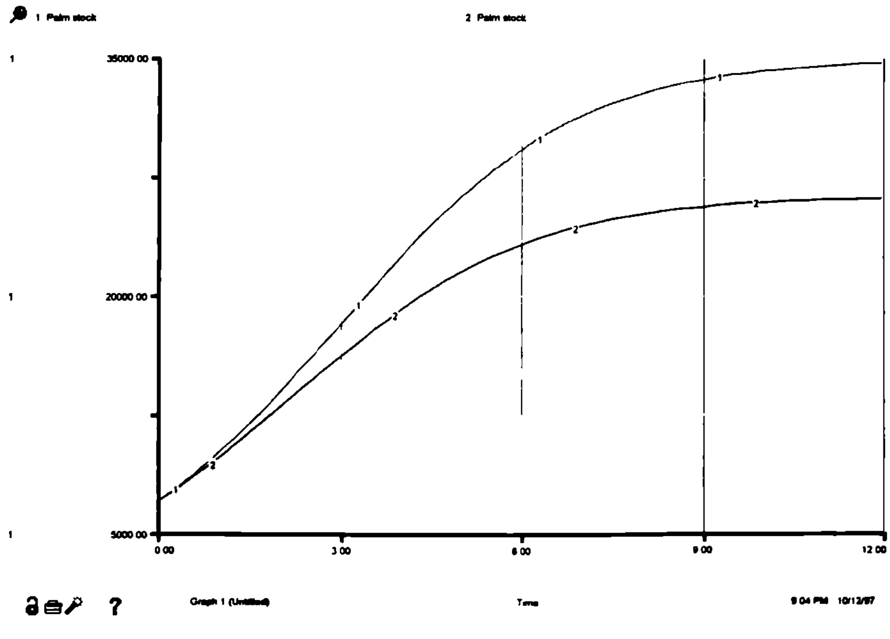


Figure 6-7: logistic growth of Palm stock when the habitat shrinks

Once this level is reached, and in the absence of other perturbations, the population stabilizes. Carrying capacity is pragmatically determined by multiplying the observed density of plants per hectare, times the area of the habitat suitable for the species. As the latter decreases over time because of land conversion, the shape of the logistic growth functions shifts downwards over time as well, as illustrated in Figure 6-7. The diagram assumes a density of 350 gruesas per ha, and a habitat of 100 has in the case of the upper curve, and of 80 has, in the case of the lower curve.

The equation for the process of Palm generation is thus:

*Palm_generation[Zone] = Palm_presence_per_zone[Zone] * Palm_stock[Zone] * Rate_of_Palm_generation[Zone] * (1 - (Palm_stock[Zone] / (1-Palm_presence_per_zone[Zone] + Habitat_carrying_cap[Zone])))*[18]

In each zone, a given percentage[19] of the various household types will be carrying out extraction activities. Extraction intensity figures (i.e. gruesas per household per annum) are based on the estimates of Chapter 5's LP model. These, in turn, are sensitive to employment opportunities off site: the better the chance of temporary employment in the oil district, the lower the extraction of Palm from the wild.

Extraction takes place mostly under condition of open access; to capture this feature, it is assumed that extraction activities will be distributed across the different ZAUs in

[18] In a standard logistic growth function, the term in the last denominator would normally be: Habitat_carrying_cap[Zone]; the term actually used (1-Palm_presence_per_zone[Zone] + Habitat_carrying_cap[Zone]) has the purpose of avoiding division by zero in the ZAUs with no recorded presence of Palm populations.

[19] Base on the field evidence discussed in chapter 4 (section 4.3.4.2.1, table 4.14, it is estimated that this percentage is of 6.5% and 2% for the buffer and influence zone, respectively.

proportion to the relative availability of Palm (proxied by the ZAU's relative share of total Palm's habitat):

*Palm_extraction[Zone] = ARRAYSUM(Extraction_per_zone[*]) * Relative_Palm_Habitat[Zone]*

Extraction per zone, in turn, is given by the usual dot product of extraction across household types:

*Extraction_per_zone[Zone] = Extractors[Zone,New] * Palm_per_Hhold[New] + Extractors[Zone,Existing_NoTitle] * Palm_per_Hhold[Existing_NoTitle] + Extractors[Zone,Existing_Title] * Palm_per_Hhold[Existing_Title]*

Extractors come from the settlers and landless farmers stocks:

*Extractors[Zone,Hhold_type] = INT((Landless_Hholds[Zone,Hhold_type] + Settlers[Zone,Hhold_type]) * Percent_gatherers[Hhold_type])*

6.2.4. Results

The various linkages between the off-site economy sector, on the one hand, and the household and land use sectors on the other, suggest that the results of the simulation will be affected by assumptions on key parameters of the former. In particular, because urban employment is the main alternative to subsistence agriculture, the aggregate volume of activity in the oil district is bound to play a major role in determining pressure on natural resource uses.

Let us therefore consider a few scenarios of income growth. Because of the likely large dependence, discussed in section 6.2.2, of regional production and income on trends in the national and world economy, hypothesizing different scenarios of income growth will help laying out the constraints within which local policy may be able to address issue of natural resource use.

6.2.4.1.Scenario A: zero income growth

This scenario represents a pessimistic extrapolation of the situation prevailing at data collection time. If income is constant, there will be no opportunities for new permanent employment, there will be stagnating or declining chances of temporary employment, and increasing number of destitute households.

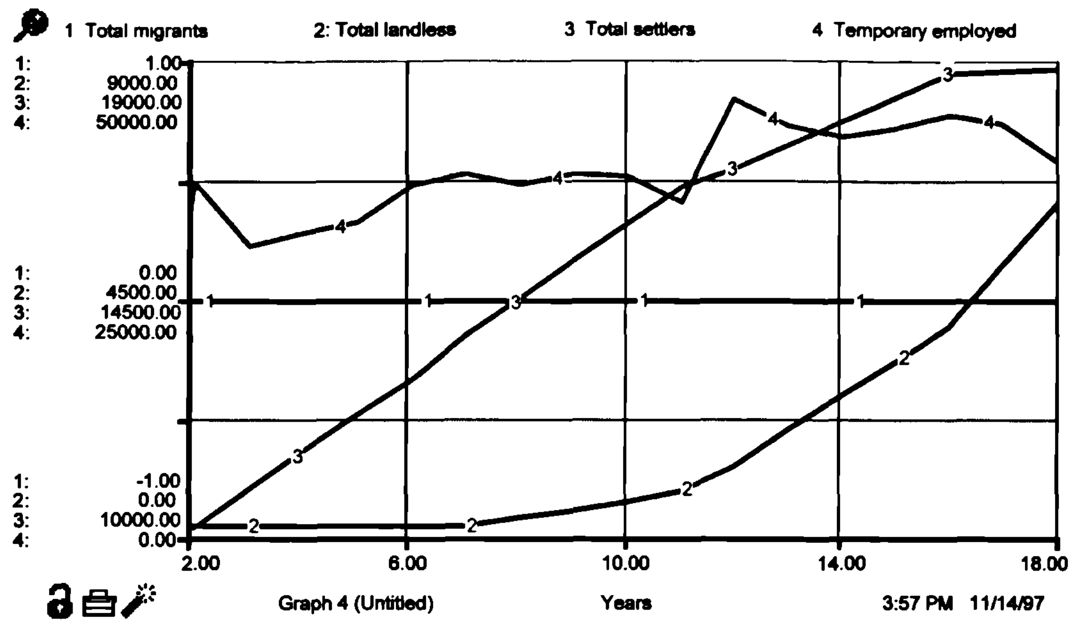


Figure 6-8. Zero income growth: migration, settlers and landlessness

(Units: temporary employment in days of work per annum; other variables in number of people)

In Figure 6-8, the number of settlers grows, but so does (and at an increasing rate) the stock of landless household. Given declining employment opportunities on the temporary job market, the supply of temporary labor stagnates.

The lack of income growth has clear implications on land use patterns. Figure 6-9 illustrates some of the most significant trends.

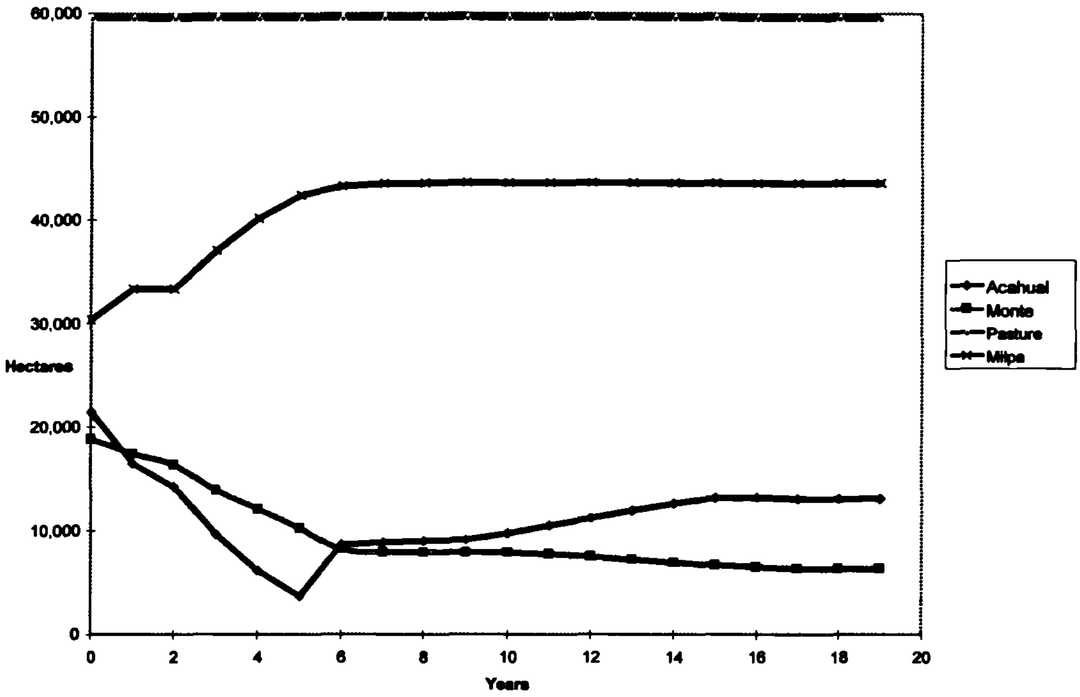


Figure 6-9 Zero income growth: land use (Has)

While pasture land is stationary (no additional demand for livestock products), farm land increases significantly at the expenses of both secondary and primary forest, in order to accommodate the subsistence needs of a growing number of aspiring settlers with no alternative income sources. The reason why *milpa* stabilizes before year 10 of the simulation is not that the demand for land decreases, but rather that communal spaces are being exhausted, as illustrated by Figure 6-10. Both primary and second growth forest in communal land shrink towards rapid exhaustion to meet space seekers' demand for land.

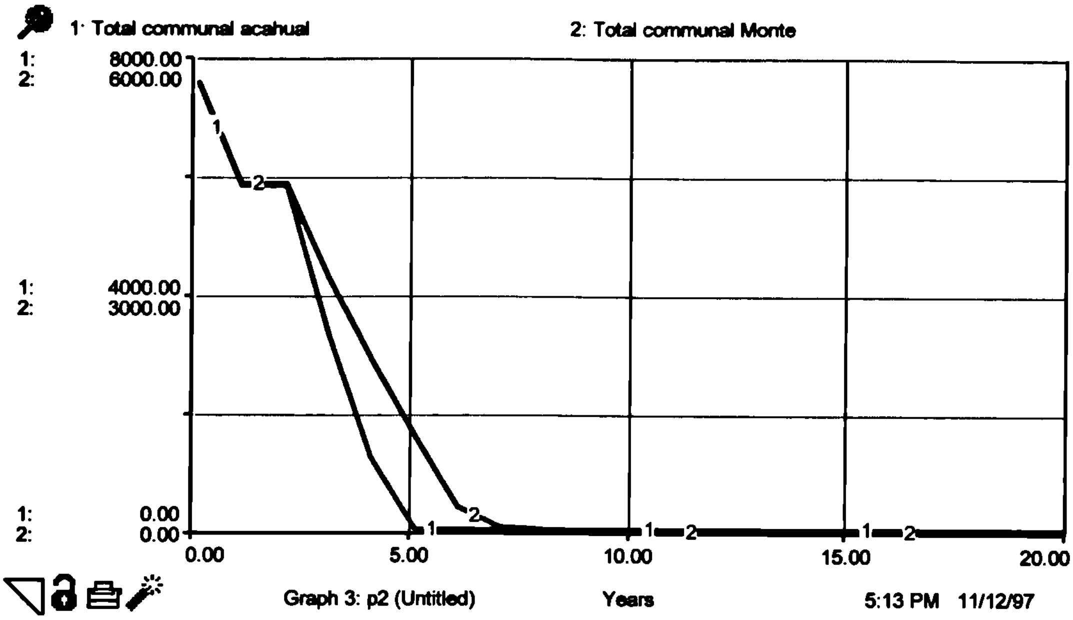


Figure 6-10 Zero income growth: forest in communal areas (Has)

Changes in private forest are driven by the need of maintaining pasture for a stationary cattle herd. As described in section 6.2.3.2 and in Annex 6-3, the rate of nutrient accumulation and of transition to mature *acahual*, as well as the speed of the overgrazing process, determine the feature of the process. If secondary succession is rapid enough, and overgrazing slow enough, the impact on primary forests may be limited. In Figure 6-11, which assumes nutrient storing time (T_n) and regeneration time (T_r) of 2 and 3 years respectively, after an initial drop due to the replacement of pregress overgrazed land, *Acahual* picks up again around the initial level; primary forest tends to stabilize at about 70% of the initial level.

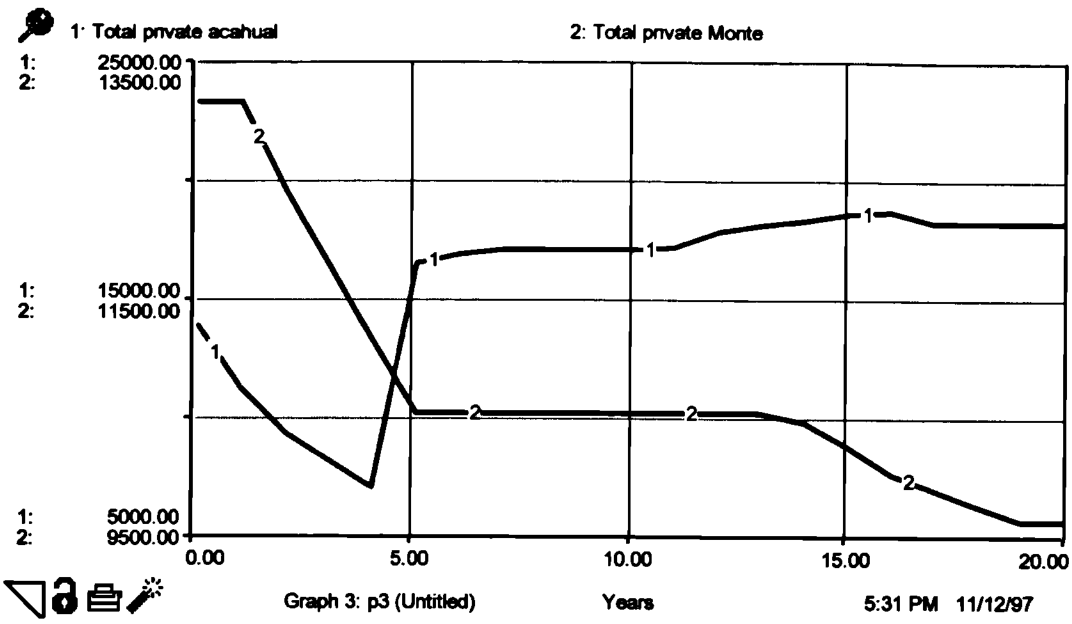


Figure 6-11 Zero income growth: forest in private land (Has)

However, if regeneration is slow and/or overgrazing fast, *monte* can quickly be depleted: with T_n=3, T_r=4 and an average duration of the overgrazing process of seven years, the entire stock of private monte is cleared after 15 years (not shown in Figure 6-11).

The high dependency of the region's households (especially those without secure land tenure) on natural resources, in the absence of other income sources, has clear impacts on Chamedor Palm populations. Figure 6-12 plots the behavior of the habitat's carrying capacity, and of the total stock of Palm (both are measured in *gruesas*). As primary forest shrinks, carrying capacity drops to the level that can be supported by the nucleus zone (due to poor access, the nucleus zone is assumed unaffected by deforestation); the Palm stock, however, is exhausted much earlier because of excessive extraction. Sensitivity analysis indicates that depletion occurs for all rates of Palm growth below 1.7.

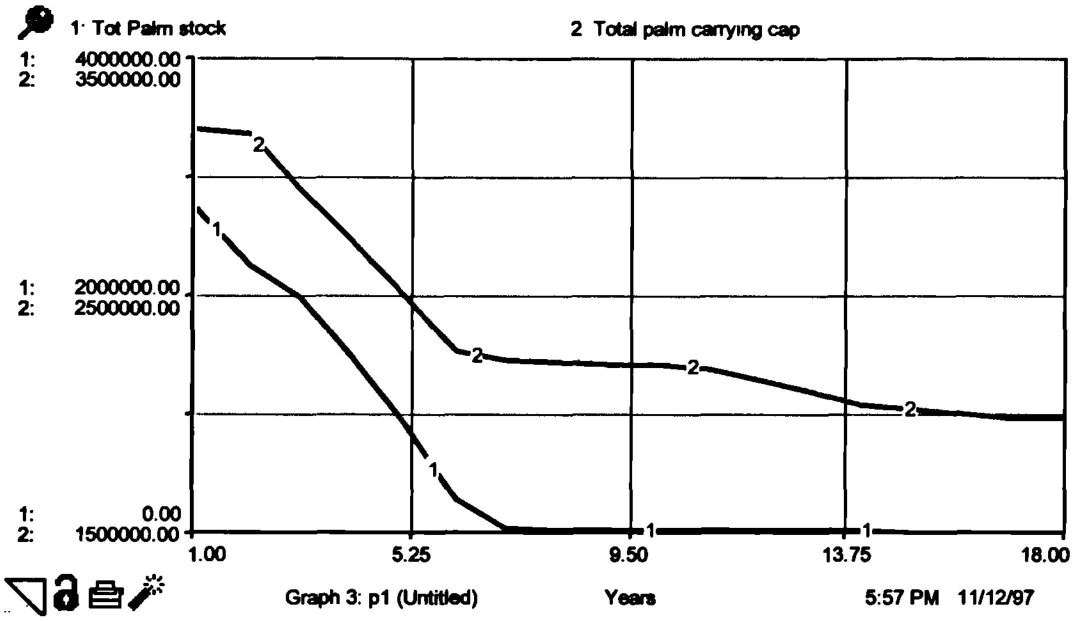


Figure 6-12 Zero income growth: Palm extraction (*gruesas*)

6.2.4.2.Scenario B: low income growth

A second scenario considers a range of low income growth rates (0 to 2%): even if the national economy overcomes the post-devaluation shock and grows at higher rates, a low rates of regional growth is plausible, at least pending industrial reorganization in the petrochemical sector. If labor intensity of production does not decrease[20], there is a slow growth in permanent and temporary employment. The overall pressure on land use however does not decrease, as the total number of settlers increase, but at least there is a significant reduction in the growth of landless households (Figure 6-13).

[20] The possibility of labor-reducing technical progress will be considered in the next scenario: it is plausible to expect that higher rates of growth will be correlated to (and perhaps dependent from) technological innovations.

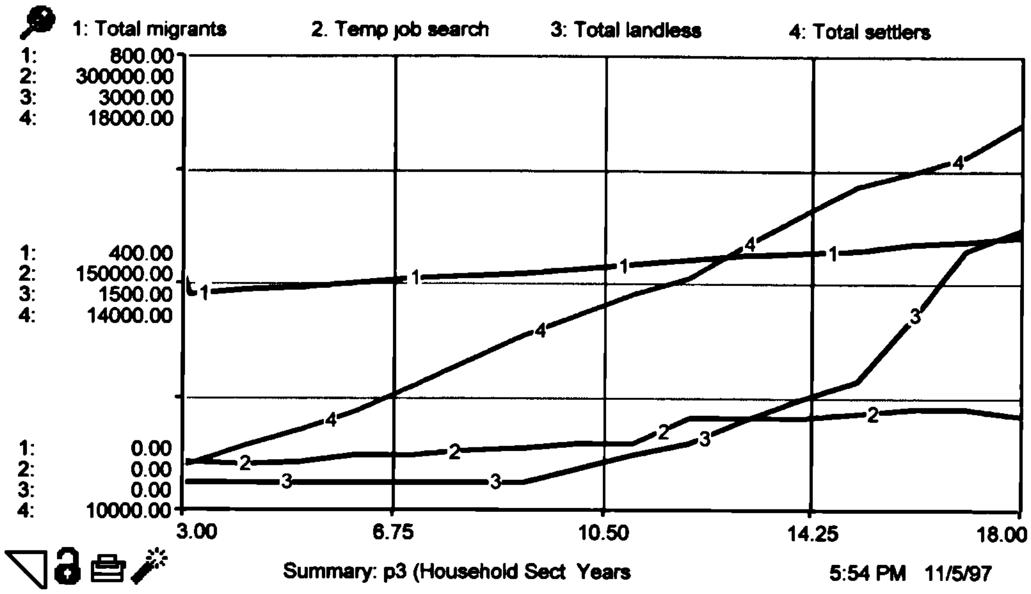


Figure 6-13 Low income growth: migration and settlement

(Units: temporary employment in days of work per annum; other variables in number of people)

The employment effects of income growth reduce somehow the pressure on land use. Figure 6-14 shows that depletion of primary and second growth vegetation in communal areas is delayed, with respect to the zero income growth case of Figure 6-10, of some 6 to 8 years.

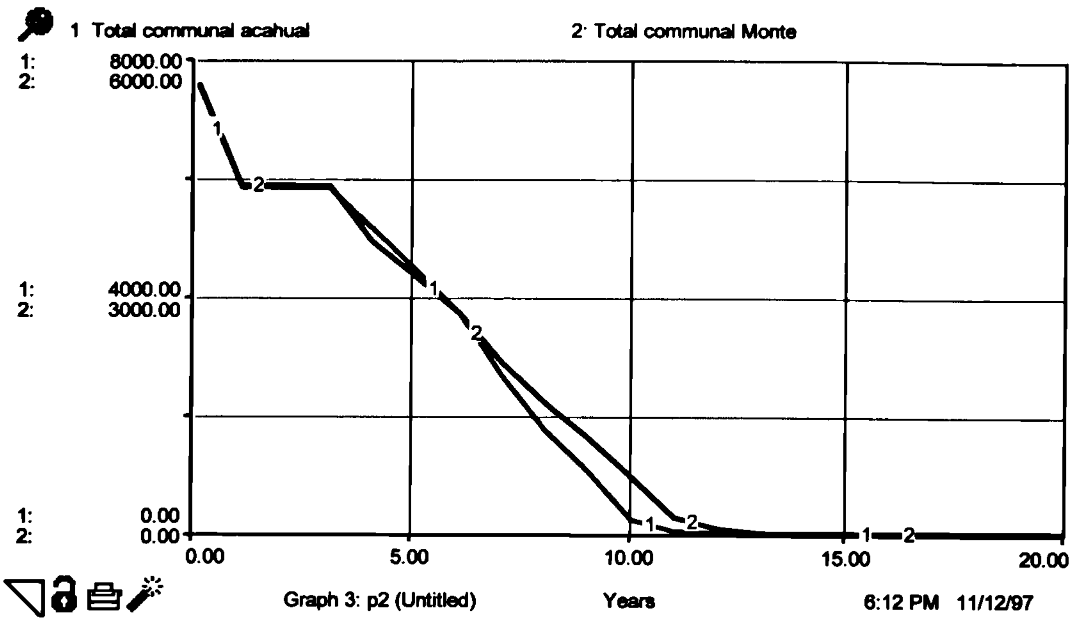


Figure 6-14 Low income growth: forest in communal areas (Has)

6.2.4.3.Scenario C: moderate income growth

Finally, let us consider an optimistic scenario in which the economy of the region grows at rates in the range 3 to 6%. Figure 6-15 (which assumes a rate of growth of 5%) shows that the employment created by fast growing production decreases settlement pressure; total number of landless households is constant at the initial level.

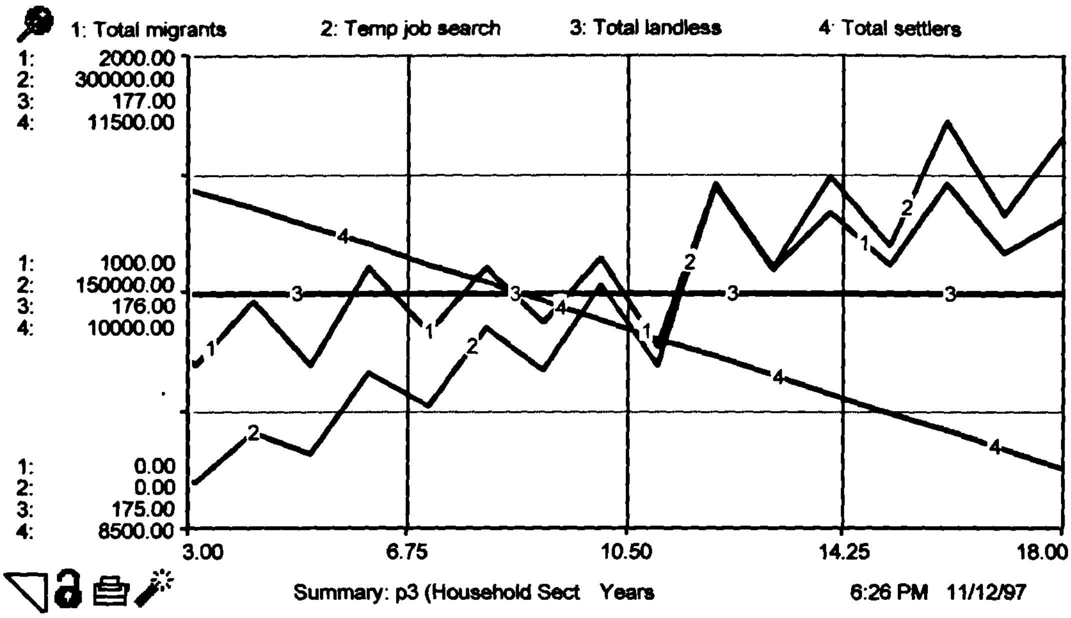


Figure 6-15 Moderate income growth: migration and settlement

(Units: temporary employment in days of work per annum; other variables in number of people)

Figure 6-16 illustrates the effects on land use: milpa does not vary, but pasture, prompted by the income-induced increase in cattle demand, increases significantly. Aggregate acahual and monte exhibit a pattern qualitatively similar to Figure 6-10: the former fluctuates and the latter drops. There is an interesting trade-off: the increase in income reduces pressure in communal areas (space seekers are absorbed by the urban labor market), but tends to increase the pressure of cattle ranching on private forests.

Whether or not the net result is a further decrease in primary forest with respect to the zero income growth case, depends partly on the income elasticity of demand for cattle, but more importantly, on the dynamics of the regeneration process. As an example, if T_n=3, and T_r=5, total *monte* at the end of the simulation drops to lower level than the zero income growth case.

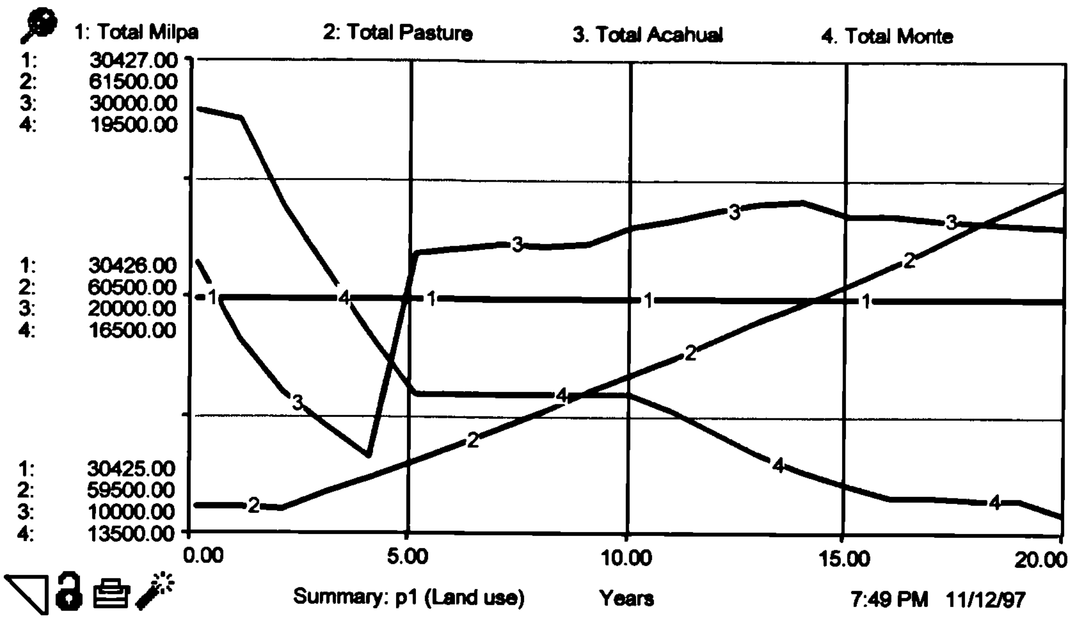


Figure 6-16 Moderate income growth: land use (Has)

A final observation for this scenario concerns the impact of labor-reducing technical progress. In Figure 6-17, a rate of income growth of 5%, accompanied by a value of technical progress (the parameter ρ in Equation 6-5) equal to 2% for both temporary and permanent work, determines a progressive reduction in the absorptive capacity of the off-site labor market, a growth in settlement, and eventually a growth in landless households. In this case, the effects of income growth on vegetation cover are unambiguously negative, as conversion will take place both in communal and private lands.

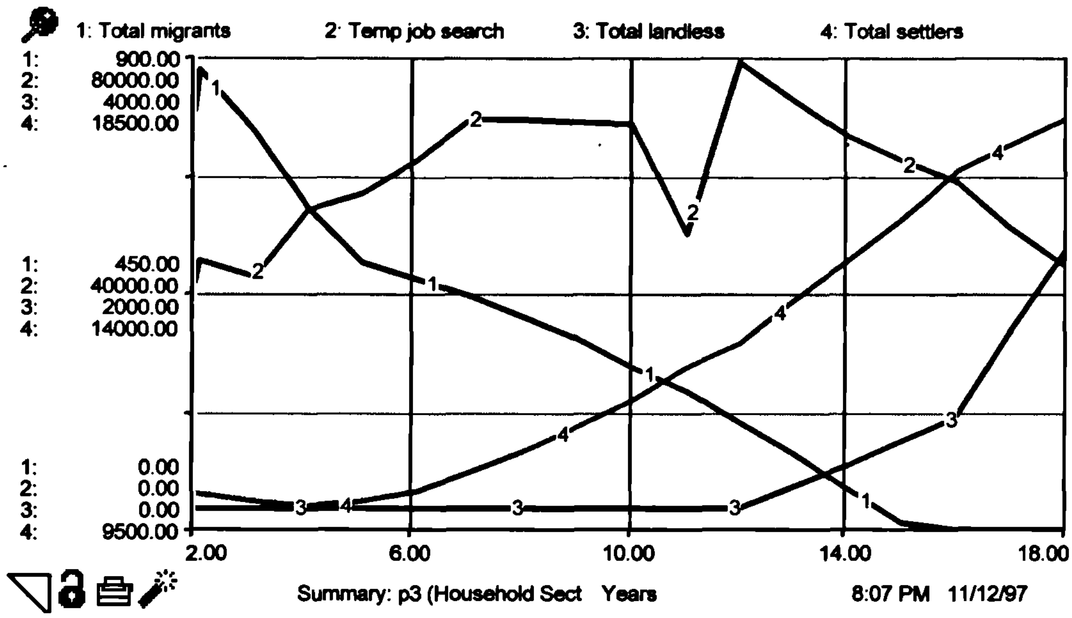


Figure 6-17 Moderate income growth and technical progress

(Units: temporary employment in days of work per annum; other variables in number of people)

6.3. Policy options for conservation and sustainable use

6.3.1. Methodological issues

As described in chapter 5, the Sierra de Santa Marta has been subject over the last three decades to significant habitat modifications. It is clear from the analysis of this chapter and of the previous one, that in the absence of policy interventions, land conversion will continue, threatening the residual forested areas in the influence and buffer zone, eventually imperiling, where topographic conditions permit it, primary forest in the core zone.

It would be difficult to argue that continuation of the land conversion process, even if incompatible with biodiversity conservation, may be consistent with the objective of enhancing local development. The LP analysis of chapter 5 has illustrated that under the predicted allocation of resources and uses of land, both newly formed and evicted households would be able to barely meet their subsistence needs.

The design of a strategy for managing the region's biological resources will need to address two set of issues: a) how to conserve the remaining areas of pristine habitat (mostly in the core and buffer zones); b) for the areas that have been partially or significantly altered by human activities (in the buffer and influence zones), what is a mix of land uses that can create a landscape complementing the biodiversity support functions of the pristine areas.

The enforcement of the formally decreed protected status of the region is sometimes invoked as the answer to the first question. It may assist in limiting extraction of flora and fauna from the nucleus zone, but it is unlikely to address the fundamental causes of land conversion, and of habitat uniformity in a landscape dominated by low-diversity uses of land such as pasture. These fundamental causes appear to be related to tenure issues, to the lack of income sources alternative to natural resource use, and to technological and financial constraints to the adoption of more diversified cropping patterns. Options for addressing these causes are addressed in sections 6.3.2, 6.3.3 and 6.3.4.

The second set of issues is particularly challenging, both from the conceptual and practical point of view. How large should the forested area be, devoted to complementing the habitat protection functions of the nucleus zone?

A strictly conservationist approach may advocate that all areas with primary and second growth vegetation be excluded from productive uses, and set aside for allowing an expansion of the continuous forested area to a level that provides the minimum habitat size for target populations of plant and animals.

The analysis of the previous sections has demonstrated that under conditions of low income growth, demographic and land tenure pressures are likely to make such a strategy not viable, unless one were to consider large scale resettlements of the resident population.

There may be an alternative approach, allowing for some type of land uses in the buffer and influence zones, which would at the same time create a managed landscape favoring biodiversity, and have beneficial effects on income and welfare of the local population. A significant challenge in the Sierra is to establish some continuity between the remaining mass of forested areas and forest fragments disseminated in the pasture and agriculture landscape.

There is a wide literature on the negative biodiversity impacts of forest fragmentation (Bierregaard, Lovejoy et al., 1992; Harrys & Silva-Lopez, 1992; Lovejoy & Oren, 1981). However, there is also a literature on the options for managing biodiversity in fragmented forests through establishment of corridors and other system of ensuring connectivity of forest remnants (Miller, Allegretti et al., 1995). Connecting fragments by fostering formation of second growth vegetation is recognized to have positive effects on diversity[21].

A number of studies undertaken in the broader Los Tuxtlas region demonstrate the importance of selected crop and plantation species (like coffee, cacao, and fruit groves) for use by rainforest animals as stepping stones to travel between forest fragments (Estrada. A. & Coates - Estrada, 1997; Guevara, 1995). Section 6.3.4 will address the basic characteristics and financial benefits of a range of productive options that may be compatible with fostering a diversified landscape beneficial to biodiversity.

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[21] " The most species rich areas are likely to be those including secondary forest in various stages of recovery" (Heywood, 1992)

6.3.2. Employment alternatives outside the study area

The analysis of section 6.2.4 has shown the importance of trends in the oil district's production to generate employment opportunities and alternative to natural resource use for the pool of "space seekers" in the study area. However, it is unlikely that strategies for the industrial restructuring of the oil district may be reoriented to take into account the detrimental impacts of declining employment on natural resources in neighboring rural areas.

To be sure, it is plausible that the gradual disengagement of the state from direct management of productive activities in the petrochemical sector will lead to stagnating level of employment and perhaps to lay-offs. Employment prospects will therefore depend upon both the labor intensity and growth in the activities of the rest of the manufacture sector, and of the trade and services sectors.

Taking into account all these different effects, it is reasonable to consider as most likely a scenario of slow growth, such as the one considered in section 6.2.4.2. Under those circumstances, it is important to examine which interventions may be devised to complement the limited effects of urban employment growth on reduced pressure on natural resources. These are discussed in sections 6.3.4.1 to 6.3.4.3.

6.3.3. Mitigating land tenure pressures

An important area is likely to be land tenure. Newly formed households and farmers who may be evicted as a result of the PROCEDE program are unlikely to have access to own resources or to credit to purchase farm land.

A first role for public policy would be facilitating settlements of disputes on land that, as a result of eviction would be returned to the community or to owners that did not exercise their rights for a long enough period of time.

A further possibility would be to explore a program of credit (perhaps based on a revolving fund structure), which would support farmers without tenure in renting or purchasing land with some vegetation cover from larger farmers, in exchange for their commitment to dedicate part of the land to agroforestry or other uses with beneficial effects on biological resources. The program may be co-funded by the State government and/or by the Municipal water commission, in recognition of the soil conservation and watershed benefits of agroforestry uses.

6.3.4. Alternative productive options

This section reviews some of the options for reorienting activities in the productive landscape in a way that would a) reduce the pressure on forest margins coming from households in the space seekers pool; b) increase financial incentives for productive activities to be undertaken by "settled" households that entail conservation of the vegetation cover.

The discussion is organized around a selected number of major crops or activities. A summary of the key issues is provided in Table 6-2.

Table 6-2: Summary of productive options for conservation and sustainable use

			Crops included in agroforestry systems		
	Maize	**Cattle**	**Coffee**	**Chamedor Palm**	**Ixtle**
Proposed strategy	Intensify cultivation	Intensify ranching	Encourage cultivation under shade in secondary forests; promote organic coffee	Promoting plantations in secondary forest	Introduce cultivation in acahual areas
Purpose	Decreasing crop area per household	Reduce pasture area per household	Increase incentives for conserving acahual areas; raise revenues per ha	Reduce extraction form the wild	Increase incentives for conserving acahual areas
Natural resources & biodiversity benefits	a) Intensification in areas not yet cleared: *milpa* space needed per household is lower; b) Intensification in areas already cleared: space opened up may be used for second growth forests; or for renting to other households	* Intensification in areas already cleared: space opened up may be used for second growth forests; or for renting farm or pasture land to other households; * If herds expand, less area needs to be cleared	Areas under shaded coffee buffer forested areas and provide habitats to several animal species	Conserve wild populations of palm, reduce disturbance to nucleus area	Acahual areas have buffering and habitat protection functions
Farm level benefits	Higher yields per has; less need to push crop areas in steeper and less fertile land	Higher returns per ha; if pasture land is scarce, less need for renting pasture outside own ranch	Provide additional cash crop income	Higher yields and revenues; decrease time spent in traveling to nucleus zone	Provide additional cash crop income
Quantitative indicator (space)	Farm area reduced of 30-50%	Pasture area potentially freed-up: 15 to 30%	May improve chances of conserving over 2,000 has of existing coffee groves and 4,000 second growth forests in 8 communities	For every 1 ha of Palm plantation, extractive pressure may be taken away from 6 has of primary forest	
Quantitative indicator (financial prospect) (a)	NPV (@15%): $140. IRR: 26%	Intensification in undergrazed pasture: IRR over 25%	IRR of coffee-based mix agroforestry systems range: 70-80%	Switching from extraction to plantation has an NPV (@ 15%) in excess of $9,000	IRR over 100%
Incentives issues	Intensification in areas already cleared: opened up space may be used for pasture rental	Freed-up areas may not be used for regeneration, but for additional grazing		If labour is abundant, extraction from nucleus zone may not decrease	
Target farmers groups	New households, existing households without secure tenure, small holders with title	Existing ranchers, mainly influence zone	Households with title, and relatively wealthy titleless households in coffee-producing area (8 communities)	Households with title, and relatively wealthy titleless households in 7 communities adjacent nucleus zone	Households with title, and relatively wealthy titleless households in several communities of buffer and influence zone

(a) Except for maize and cattle, the figures refer to the NPV and IRR of per hectare crop budget. Because they do not take into account the opportunity cost of the next most profitable use of land, the existence of credit constraints, and the cost of training and capacity building, they are likely to overestimate the profitability of the crop. More complete measure of financial efficeincy are provided byfarm, and not single crop models. These are briefly described in a later subsection.

6.3.4.1.Maize intensification

It is widely recognized that one of the key factors of deforestation induced by swidden agriculture is the low productivity per hectare of key staple crops sowed by subsistence farmers in rain fed land (Southgate, 1991; Southgate, 1995; Barbier & Burgess, 1996). If credit, information or capacity constraints prevent access to productivity - raising technology, total yields can only be increased by increasing planted areas. In the Sierra de Santa Marta, a detailed analysis of constraints to, and opportunities for, intensifying baize-based systems has recently been provided by (Buckles & Erenstein, 1996)

According to these authors, current patterns of maize cultivation are characterized by relative large size of total crop area per household, and relatively long fallow times (six years before new clearance and use for cultivation). Sustainable intensification of the current system would be achieved through a combination of technologies that increase fertility (green manures and fertilizers) and that ensure better conservation of existing fertility (green manures, shelter belts and live barriers in contour lines).

Based on this combination, it would be possible to reduce (in an equilibrium that would follow a transition period of one to three years) fallow time to just one year, and decrease total crop area to 33% or 50% of the original parcel size, depending on whether the intensification technology is applied to the buffer or the influence zone.

Farm-level cost - benefit analysis suggests that the "with" intensification case is financially more attractive than the "without" case in the total period considered. Detailed results for the buffer zone are summarized in Table 6-3, which reports the incremental benefits and costs for the transition from a total farm area of 6 has to an intensified parcel of 2 has. Despite an IRR exceeding 26%, there is a marked difference between the initial years and later years. In particular, the first four years of the "with" case are not particularly attractive, and entail a net loss to the household. This raise issues of funding options, which will be discussed in section 6.3.5.

Table 6-3 Financial Benefit -Cost Analysis of maize intensification (buffer zone)

México
Sierra de Santa Marta: parcelas agroforestales
Finca Zona Amortiguamiento (Entry year 3) Household Model
FINANCIAL BUDGET (DETAILED)
(In US $)

	Increments									
	1	2	3	4	5	6	7	8	9	10
Main Production										
Maiz	-50.0	50.0	182.5	62.5	158.3	224.2	104.2	170.8	224.2	224.2
By Products										
Procampo	-34.9	-34.9	-34.9	-	-	-	-	-	-	-
Leña	-23 8	-	-	-47.6	-	-	-47 6	-	-	-
Sub-total Byproducts	-58 7	-34 9	-34 9	-47.6	-	-	-47 6	-	-	-
Gross Value Of Production	-108.7	15.1	147.6	14.9	158.3	224.2	56.5	170.8	224 2	224.2
Production Cost										
Investment										
Purchased Inputs										
Otros insumos abonos verdes	3.6	3.6	3 6	3.6	-	-	-	-	-	-
Otros insumos hedgerow	14.3	14.3	14 3	14.3	-	-	-	-	-	-
Sub-Total Purchased Inputs	17.9	17 9	17 9	17 9	-	-	-	-	-	-
Hired Labor										
Mano de obra Enero	26.2	26.2	26 2	26.2	-	-	-	-	-	-
Mano de obra Deciembre	8 3	8.3	8.3	8.3	-	-	-	-	-	-
Sub-Total Hired Labor	34.5	34 5	34 5	34.5	-	-	-	-	-	-
Sub-total Investment Costs	52.4	52.4	52.4	52.4	-	-	-	-	-	-
Operating										
Purchased Inputs										
Depreciacion implementos	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-	-	-
Fertilizante: Urea	10.5	21.0	31.4	31.4	21.0	10.5	-	-	-	-
Fertilizante: DAP	10 0	20.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Semillas	-1 6	-1 6	-1 6	-1.6	-1 6	-1.6	-1 6	-1.6	-1.6	-1 6
Sub-Total Purchased Inputs	16.5	37 0	57.4	57.4	47.0	36.5	26.0	28.4	28.4	28.4
Hired Labor										
Mano de obra Enero	-	6.0	11.9	11.9	17.9	17.9	17.9	17.9	17.9	17.9
Mano de obra Febrero	-26.2	-19 0	-21.4	-40.5	-23.8	-23.8	-42.9	-23.8	-26 2	-26.2
Mano de obra Marzo	-6.0	-4.8	-3 6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6	-3.6
Mano de obra Abril	9.5	19.0	28.6	28.6	23.8	19.0	14.3	14.3	14.3	14.3
Mano de obra Julio	-29.8	-53.6	-95.2	-47.6	-77.4	-107.1	-59.5	-83.3	-113.1	-113.1
Mano de obra Agosto	-7.1	-7.1	-7 1	-7.1	-7.1	-7.1	-7.1	-7.1	-3.6	-
Mano de obra Septiembre	-2.4	6.4	17.7	8.9	16.3	21.2	12.4	17.4	21.2	21.2
Mano de obra Octubre	-6 9	10.9	34.0	14.5	30.5	41.3	21.7	32.7	41 3	41 3
Mano de obra Noviembre	-4.5	4.5	16.3	5.6	14.2	20.1	9.3	15.3	20.1	20.1
Mano de obra Deciembre	-	6.0	11.9	11.9	17.9	17 9	17 9	17 9	17 9	17.9
Sub-Total Hired Labor	-73 3	-31 8	-7 0	-17 5	8 6	-4 4	-19 6	-2.5	-13 9	-10 4
Sub-total Operating Costs	-56.8	5 2	50 4	39 9	55 5	32.1	6.4	25.9	14 5	18 0
Sub-Total Production Cost	-4.5	57 6	102 8	92.3	55 5	32.1	6 4	25.9	14.5	18 0
OUTFLOWS	-4.5	57 6	102 8	92.3	55.5	32.1	6.4	25.9	14.5	18.0
Cash Flow Before Financing	-104.3	-42.5	44 8	-77.4	102.8	192.1	50.2	144 9	209.7	206.1
Financial Inflows										
Transfer from Previous Period	-	57 6	102.8	92.3	55.5	32.1	6.4	25.9	14 5	18.0
Contribution from own savings	12.7	-	-	-	-	-	-	-	-	-
Sub-Total Financial Inflows	12.7	57.6	102 8	92.3	55.5	32.1	6.4	25.9	14.5	18 0
Financial Outflows										
Transfer to Next Period	57 6	102.8	92 3	55 5	32.1	6 4	25 9	14.5	18 0	18 0
Net Financing	-44 9	-45 2	10 5	36 8	23 5	25 7	-19 5	11 4	-3 6	-
Cash Flow After Financing	-149 2	-87.7	55 3	-40.7	126 2	217.8	30 6	156.4	206.1	206.1
Change in Net Worth	-96.0									
Contribution from own savings		-	-	-	-	-	-	-	-	-
Residual value of										
Transfer to Next Period	-	-	-	-	-	-	-	-	-	18 0
Sub-Total Change In Net Worth	-12.7	-	-	-	-	-	-	-	-	18 0
Farm Family Benefits After Financing	-161 8	-87 7	55 3	-40 7	126 2	217 8	30.6	156 4	206 1	224 2

IRR = 26.1%, NPV = 139.58

(Source: author calculations based on (Buckles & Erenstein, 1996) and (Cervigni & Ramirez, 1997).

6.3.4.2. Cattle ranching intensification

Section 6.2.4 has discussed the range of possible impacts on land use coming from livestock activities. In all cases where a previous record of overgrazing and/or increase in the demand for livestock product exceeds the regeneration potential of pasture and fallow land, conversion of primary forest is likely to take place. A strategy for natural resources-conscious management of livestock in the region may be based on raising stocking rates (number of cattle heads per hectare).

For undergrazed pastures, increases in the stocking rate would be achieved mainly by increasing the numerator of the ratio: herd expansion could be made possible on existing pasture, without bringing new one under use[22]. In the case of overgrazed pastures, the approach would focus on decreasing the denominator of the ratio: higher stocking rates would make it possible to concentrate grazing in the least degraded pasture, and freeing up the most degraded ones for nutrient storing, vegetation succession, and eventually for possible later use in agriculture, or in the establishment of vegetation corridors.

There are number of reasons for the prevailing low stocking rates in the Sierra. These include the scarcity of technical assistance for management of fodder and livestock; herds' genetic characteristics unsuitable for production of milk and meat in tropical environments; low quality and poor management of fodder, resulting in low yields; scarcity of food

[22]In the terminology of Annex 6-3, the approach would be equivalent to increasing the s* parameter, i.e. the pasture's carrying capacity.

supplement measures during droughts; scarcity of preventive medical control , limited veterinarian services and low hygiene standards.

A study developed by FAO in the context of the GEF-PSSM research on the Sierra de Santa Marta[23], proposes models for livestock intensification, which aim to achieve higher levels of production of milk and meat per animal and per hectare. The models apply several technologies to improve livestock management through betterment of fodder and other foods resources, and enhancement of animal quality.

The models suggest that it may be possible to increase herd numbers by 35% and 100%, and decrease pasture use by 15% and 30%, for undergrazed and overgrazed pasture, respectively. The attractiveness of intensification measures would critically depend on credit conditions and on prevailing output prices.

For example, if investments are funded at a concessional rate of 5%, and dairy and meat prices increase by 20% following expansion of demand, intensification in undergrazed pasture generates internal rates of return above 25%.

A key element of success of an intensification strategy would be the presence of a clear link between the new technology and the land use patterns prevailing <u>after</u> their adoption. Ranchers contemplating expansion of their herds may be offered public support in the form of credit or technical assistance for adopting land intensive technologies; similarly, ranchers managing existing pasture may be offered a technological package for increasing existing herds but using less pasture.

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[23] See (Cervigni & Ramirez, 1997) for details.

In both cases, continuation of support would be conditional on the ranchers allotting the land savings (land not converted in one case, freed up from pasture in the other) not to further increases in herds, but to vegetation regeneration or, given the demand for land coming from space seeking households, to agriculture, via rental arrangements.

6.3.4.3.Agroforestry options

Agroforestry is a productive strategy whereby woody species with multiples uses are deliberately mixed in the same plot with crops and/or animals in spatial arrangements or in time sequences. On a plot with agroforestry management, timber and non-timber species can coexist with short cycle, semi-permanent crops and with forage plants for semi-stabled livestock.

Promoting agroforestry systems in the Sierra would contribute to the conservation of remaining forests, and help reclaim degraded lands for re-conversion to diversified systems of production. Agroforestry may make it possible for forest fragments that are currently geographically and biologically separated, to be consolidated. This would create additional habitat for several animal species, and facilitate dissemination of seeds carried by birds (Aguilar-Ortiz, 1982). The rest of this section will discuss options for systems based on Chamedor Palm, Coffee (in isolation or in association with other tree crops), *Ixtle*.

Chamedor Palm

As documented by field evidence, and confirmed by the predictions of this chapter's model, Chamedor palm is currently one of the plant species threatened by excessive exploitation. Despite this, it continues to be harvested clandestinely, with a drastic decrease in wild populations, and negative effects on forested areas especially in the nucleus zone.

One option for addressing the problem is to encourage substitution of harvesting from the wild with cultivation outside primary forests in the nucleus and buffer zones. Areas indicated for cultivation of Palm are those that have a canopy providing the shade required; the most suitable are remnants of forests, second growth vegetation, or those associated with perennial tree crops such as coffee plantations, or other agroforestry systems.

Table 6-4 proposes a scheme for transition from extraction to cultivation, to be undertaken in conjunction with maize intensification, as discussed earlier (section 6.3.4.1). With the more intensive technology, maize cultivation requires about one third of the *acahual* area otherwise needed. The surplus area not converted (in this example 2 has) can be used for cultivation of Palm which would otherwise be extracted over a 12 has area of *monte*.

Table 6-4 Palm: from extraction to cultivation

México
Sierra de Santa Marta: parcelas agroforestales
Cultivo de Palma Modelo familiar
CROPPING PATTERNS
(In Units)

	Unit	Without	With
Cropping Intensity	Percent	100	100
Cropping Pattern			
Existing Technology			
Milpa		3.00	0.00
Palm (Extraction from Monte)	ha	12	-
Sub-total Existing Technology		15	-
New Technology			
Palma (Cultivation in Acahual)	ha	-	2
Milpa	ha	-	1
Monte (idle)	ha	-	12
Sub-total New Technology		-	15
Total Cropped Area		15	15

In financial terms, the transition is quite attractive: cultivated Palm sells at higher price (because of better quality), and has higher yields. Table 6-5 reports incremental cost and benefits to the transition for a representative 3 adults household[24]. After the first two years, the household is better off with the maize intensification/ palm cultivation combination than without it; using a discount rate of 15%, the NPV of the transition exceeds $9,000 over a 10 years time horizon[25].

[24] The calculation assumes a supply of labor for off-farm employment of 90 days per annum, in line with the prediction of chapter 5 LP model.

[25] An analysis of more comprehensive cropping patterns, involving other crops in addition to maize and palm is provided in one of the farm level model described in section 6.3.5.

Table 6-5 from extraction to cultivation of Palm: financial analysis

México
Sierra de Santa Marta: parcelas agroforestales
Cultivo de Palma Modelo familiar
FINANCIAL BUDGET (AGGREGATED)
(In US $) /a

	Increments									
	1	2	3	4	5	6	7	8	9	10
Main Production										
Palmas y semillas	-	-107 9	223.7	1,219 0	3,079 2	4 940 0	5,574 9	5,574 9	5,574 9	5 574 9
Productos de milpa	-	8 3	51 7	31 3	64 6	105 8	52.1	85 4	112 1	52 1
Sub-total Main Production	-	-99 6	275 3	1 250 2	3,143 8	5 045 8	5 627 0	5 660 3	5 687 0	5 627 0
By Products										
Procampo	-	-17 5	-17 5	-17 5	-	-	-	-	-	-
Productos Intermedios	-	11 9	-	-23 8	-	-	-23 8	-	-	-23 8
Sub-total Byproducts	-	-5 6	-17 5	-41 3	-	-	-23 8	-	-	-23 8
Gross Value Of Production	-	-105 2	257 9	1 208 9	3,143 8	5,045 8	5 603 2	5 660 3	5 687 0	5 603 2
On-Farm Consumption										
Productos de milpa	-	-	-	-	-	-	-	-	-	-
Net Value Of Production	-	-105 2	257 9	1,208 9	3 143 8	5 045 8	5 603 2	5 660 3	5 687 0	5 603 2
Off Farm Employment										
Mano de Obra	-	-	-	-43 0	-71 4	-71 4	-71 4	-71 4	-71 4	-71 4
Purchased Consumption										
Productos de milpa	-	-8 3	-51 7	-	-26 7	-53 3	-	-26 7	-53 3	-
INFLOWS	-	-96 8	309 5	1,165 9	3,099 0	5,027 7	5,531 8	5,615 6	5,668.9	5,531 8
Production Cost										
Investment										
Purchased Inputs										
Insumos para Palma Camedor	-	72 5	72 5	144 9	-	-	-	-	-	-
Insumos para Mais	-	8 9	8 9	8 9	8 9	-	-	-	-	-
Sub-Total Purchased Inputs	-	81.4	81 4	153 8	8 9	-	-	-	-	-
Hired Labor										
Mano de Obra	-	-	-	39 3	4 2	-	-	-	-	-
Sub-total Investment Costs	-	81 4	81 4	193 1	13.1	-	-	-	-	-
Operating										
Purchased Inputs										
Insumos para Palma Extractiva	-	-32.4	-48 6	-97 1	-97.1	-97 1	-97.1	-97 1	-97.1	-97 1
Depreciacion implementos	-	-1 2	-1.2	-1 2	-1 2	-1 2	-1 2	-1 2	-	-
Insumos para Mais	-	9 4	19 7	29.9	29 9	24 7	19 4	14 2	14 2	14 2
Costos oportunidad	-	0 1	0.1	0.2	0 2	0 2	0 2	0 2	0 2	0 2
Sub-Total Purchased Inputs	-	-24 1	-30 0	-68 2	-68.2	-73 5	-78 7	-83.9	-82 8	-82 8
Hired Labor										
Mano de Obra	-	-	-	-	278.1	753 8	754 3	754 3	754 3	754 3
Sub-total Operating Costs	-	-24 1	-30 0	-68 2	209 9	680 3	675 6	670 3	671 5	671 5
Sub-Total Production Cost	-	57 3	51 4	124 9	223 0	680 3	675 6	670 3	671 5	671 5
Other Outflows										
Gastos Familiares	-	-	-	-	-	-	-	-	-	-
OUTFLOWS	-	57 3	51 4	124 9	223 0	680 3	675 6	670 3	671 5	671 5
Cash Flow Before Financing	-	-154 1	258 1	1 041 0	2 876 0	4 347 5	4 858 2	4 945 2	4 997 4	4 860 2
Farm Family Benefits Before Financing	-	-154 1	258 1	1 041 0	2 876 0	4 347 5	4 858 2	4 945 2	4 997 4	4 860 2
Net Financing	7 7	3 6	-44 1	-58 9	-274 4	2 8	3 1	-0 7	-	-
Cash Flow After Financing	7 7	-150 6	214 0	982 2	2 601 7	4 350 3	4 859 3	4 944 5	4 997 4	4 860 2
Change in Net Worth										
Contribution from own savings	42.0	-	-	-	-	-	-	-	-	-
Residual value of										
Transfer to Next Period	-	-	-	-	-	-	-	-	-	402 9
Sub-Total Change in Net Worth	-42 0	-	-	-	-	-	-	-	-	402 9
Farm Family Benefits After Financing	-34 4	-150 6	214 0	982 2	2 601 7	4 350 3	4 859 3	4 944 5	4 997 4	5 283 2
Returns per Family-Day of Labor	-	-	-	-	-	-	-	-	-	-
Incremental Returns per Incremental Family-Day of Labor	-	-	-	-	-	-	-	-	-	-

IRR = 237 5%, NPV = 9,897 45

The transition is more labor intensive, but the incremental labor requirement (not reported in the table, but ranging between 12 and 540 days per annum) is well within the limits of labor available within the household. High levels of international demand seem to offer promising prospects for absorbing the expansion of Palm production that would follow the transition from extraction to cultivation.

Coffee

Coffee groves under shade trees mimic the conditions of natural forest, by re-creating the combination and association of flora and fauna that prosper in that habitat (Jimenez Avila & Gomez Pompa, 1982). For this reason, it is now increasingly recognized that coffee groves have significant biodiversity protection functions, in that they serve as a refuge for numerous species of plants and animals (Wille, 1994), and entail maintenance of the tree cover to be used as shade[26]. In addition, coffee offers other environmental advantages, such as: (i) watershed protection; (ii) soil conservation in hillside (both because of the protection from the action of rain and the contribution that organic material from the shade trees makes to soil nutrient balance); (iii) carbon storage.

Coffee production can be promoted in association with other profitable crops either in existing groves or in lands that can be freed up through agriculture and cattle intensification.

Organic Coffee

Some existing groves may be converted to organic coffee[27]. In addition to the agroecosystem stability and soil protection benefits of ordinary shaded coffee, organic coffee production has distinct marketing advantage: it sells at relatively high prices, and has the potential of tapping into high-end market niches that commercial varieties can not

[26] According to indications provided by its staff, the World Bank is preparing biodiversity projects in Central American countries such as El Salvador, consisting in support to cultivation of coffee under shade.

reach. Marketing advantages may offset the lower yields of organic coffee: financial analysis suggest that for output price ratios in excess of 1.6, organic varieties dominate commercial coffee.

Coffee-based mixed systems

These systems consist of associating coffee with one or more tree crops products in a single plot. The associated crops are selected on the basis of agro-ecological criteria (e.g., they should occupy a specific place in the structure of the coffee plantation, so as to provide shade for the coffee and an additional product); and on the basis of market niches considerations.

Based on the successful experience of the Córdoba-Huatusco region, in the Sierra de Santa Marta it would be desirable to promote mixed systems such as (Rodríguez, 1994): coffee-Chamedor palm, coffee-"tepejilote," coffee-banana-orange, coffee-banana, and coffee-Persian lemon. Crop budget financial analysis suggest that internal rate of returns[28] to the establishment of coffee-based mixed agroforestry systems range between 70 and 80%.

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[27] Prompted by visits of ISMAM and UCIRI, two of the principal indigenous organizations that produce organic coffee, some farmers in the communities of San Fernando, Ocotal Grande and Ocotal Chico have already started training in organic production techniques.

[28] As noted in Table 6-2, these figures refer to the IRR of per hectare crop budget. Because they do not take into account the opportunity cost of the next most profitable use of land, the existence of credit constraints, and the cost of training and capacity building, they are likely to overestimate the profitability of the crop. More complete measure of financial efficiency are provided by <u>farm</u> models (as opposed to single crop models). These are briefly described later, subsection 6.3.5.

Ixtle

The Ixtle (Achmea magdalenae (André) André ex Baker)), is a plant of the Bromeliacea family that is found distributed from sea level to 800 meters above sea level in the region of Los Tuxtlas. This plant develops in the shade of the high forest, in very moist places. Currently, the fiber is used as the "heart" of lassos, highly durable cables to edge belts and other leather items, and has Japan as one of the main export markets. Intensive use has led to over-exploitation of the wild populations, seriously endangering the existence of this resource in the southeastern part of the country[29].

The growing of Ixtle requires lands in second growth vegetation or high forests, with 70% shade and up to 50% slopes. The most suitable land for this crop is located in communal lands of the buffer zone, and in second growth and primary forest fragments in the influence zone. Ixtle could also be introduced in coffee plantations.

Dealers pay local producers from N$80.00 to N$150.00 per kilogram of fiber, selling it later primarily in the States of Jalisco and Oaxaca and Mexico City, at N$300.00 or more per kilogram. Crop budget financial analysis suggest that the rate of return to Ixtle plantations exceeds 100%[30].

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[29] Since pre-Hispanic times, the fiber obtained from its leaves has been valued because of its durability and endurance for the production of fishing lines and nets, cords, for sewing clothes and footwear and making bags, sacks, etc. During the colonial period and up to the last century, the fiber obtained from this plant was the region's principal export product.

[30] The same caveat of footnote 28 applies, concerning the likely overestimation of financial efficiency provided by single crop budgets.

6.3.5. Implementation and costs of the alternative productive options

The previous discussion of alternative productive options has been conducted at the level of individual crop or activity. However, according to the evidence of chapter 4, few if any household practice mono-cultivation. Cropping patterns are typically based on a combination of different crops and activity. Therefore, the implementation of the proposed sustainable use measures would need to work through changes in baseline cropping patterns, that the farm would choose to undertake to raise its income and living standards. Policy interventions may be needed to facilitate the farm' access to the necessary improved technology, credit and training.

The optimal cropping pattern that the farm would select could be determined by straightforward extensions of the LP models of chapter 5. This exercise would also provide indications on the volume of credit and training per household that the transition to the alternative productive option would require. For reasons of time and space, this has not been attempted here.

However, indications about the range of resources required for implementation may be obtained from farm budget models[31] developed by the author of this dissertation in the context of the previously mentioned GEF-PSSM study. Three agroforestry models are proposed and analyzed in financial terms . The models are conceived so that they can be applied to areas with different geographical, ecological and social features. The common

[31] These consist of comparing a "without", and "with" project situation, whereby the "without" is an average cropping pattern of a prototypical farm, and the "with" is an alternative cropping pattern, that achieves the selected environmental objectives, and that is likely to make the farm better off. The "with" cropping pattern is determined on the basis of expert judgment, and not on an explicit model of farm optimization.

prerequisite for the different agroforestry options is the intensification of subsistence farming and small -medium scale livestock ranching.

The first model (A) relates to holdings bordering the core zone. The proposed strategy involves intensification of maize growing, gradual establishment of a two hectare Chamedor palm plantation, gradual replacement of single crop coffee with mixed crop systems, and livestock intensification.

The second model (B) is designed for application to the coffee growing area in the upper southern slopes of the study region. The model entails maize intensification and use of the freed-up space for mixed crop coffee (coffee-banana-orange), replacement of traditional coffee with organic coffee, and livestock intensification linked to conservation of the existing vegetation cover.

The third model (C) is proposed for farmers and ranchers located on the lower slopes of the southern part of the study area. The model envisions intensification of both maize production and cattle ranching, and adoption of agroforestry systems based on high value crops, like Ixtle, in the second growth areas freed up through intensification.

Table 6-6 Agroforestry models: summary of credit and training requirements

Model	Land units	Area	Proposed number of participating households	Investment credit per household	Revolving funds	Short term credit per household	NPV (@ 15%)	Benefit/ cost ratio	Training cost per household
	Units	Has	Unidades	US$	US$	Average US$/ year	US$		US$
A Total	7	5,069	100	1,775	86	80	$1,348,343	2.30	$414
B Total	8	13,800	215	3,790	86	501	$3,516,553	2.30	$412
C Total	16	34,898	215	1 690	86	949	$3,691,161	3.60	$531

Table 6-6 summarizes the credit[32] and training cost requirements for the three models. With access to training worth an average of $400, to investment credit in the range of US$ 1,850 to 3,800, and short-term credit in the range of US$ 80-900 per annum, household adopting the proposed alternative technologies would be able to obtain NPVs between US$ 70-300 per household per hectare, with benefit cost ratios well in excess of 2.

6.3.6. Funding issues

The productive options discussed in section 6.3.4 and subsections establish the foundations of a natural resources management strategy that enhances the well-being of local households, while contributing to conservation and sustainable use of biodiversity. The analysis of funding options for such a strategy clearly relates to chapter three's discussion of incremental cost; it has implications that go beyond the particular case of the Sierra, as it touches on issues that are likely to emerge in a number of projects that promote sustainable use of biodiversity, thereby generating "incremental domestic benefits" in the language of chapter 3.

On the one hand, improved prospects for biodiversity conservation would justify some form of support from the international community. On the other hand, innovations which are financially attractive for the individual producer or resource users, such as those considered here, may well be part of a reasonable "baseline" development path, that local

[32] Three credit instruments are considered, all of which represents application of schemes already present in the region, as discussed in chapter 4: a) revolving funds, which, much in the spirit of the existing "Credito a la Palabra" program, would cover costs related to maize production under the proposed intensification system; b) Investment credit, disbursed at concessional conditions, similar to those applied by INI for its forest plantations program; c) Short term credit, disbursed at conditions similar to those of INI' s coffee program

and national policy makers would adopt in the absence of the Convention on Biological Diversity and of its financial mechanism.

This observation raises two sets of issues, concerning the scope and the type of funding to be provided in these cases by the International Community through the GEF mechanism.

On the scope for GEF involvement, measures included in the baseline do not normally qualify for incremental cost financing. However, GEF policy documents (Global Environment Facility, 1996; Global Environment Facility, 1996a) recognize that there may be barriers preventing countries from adopting resource management choices, that are both biodiversity - friendly and consistent with national development. These barriers may be of an institutional, technological, informational nature.

For example, knowledge about land savings and soil conserving agriculture technologies may not be widespread among farmers, and the country's institutional infrastructure may not be adequate to cater for the necessary extension services. GEF funding could then be used for removing obstacles of these nature, and enabling country's stakeholders to prefer biodiversity friendly options over those that would be selected in a resource-constrained baseline.

On the second issue (forms of GEF financing), virtually all of GEF projects so far have been funded with grants. However, based on provisions of the GEF Instrument (Global Environment Facility, 1994), policy work has been undertaken in the GEF (Global Environment Facility, 1996b) to explore other funding options, besides grant, which could be used to support eligible activities. These include concessional and contingent loans, and guarantees to buy down risk and encourage the investment of private capital.

With respect to activities such as those discussed above, a variety of funding approaches could be used, to encourage their inclusion in an "environmentally reasonable" development baseline. Cost efficiency considerations would suggest to follow a strategy which maximizes the opportunities for complementarity between domestic and foreign sources of funding.

In particular, GEF resources may be used to fund pilot projects that would demonstrate the technical and financial feasibility of biodiversity sustainable use options (intensification technologies and agroforestry schemes in the case of the Sierra). Once key barriers are removed, the expansion on a larger scale of the alternative productive options would be more appropriately supported, rather than via continued GEF funding, through conventional development assistance, to be provided by multilateral or bilateral aid agencies.

Alternatively, if activities to be encouraged were confined to relatively small areas like the Sierra, in which lending volumes may be too low to recoup the relatively large overhead cost incurred by agencies like the World Bank in preparing and implementing a credit operation, GEF funding may still be considered. However, non-grant modalities may be particularly appropriate. For example, a revolving fund could be established, which would provide short and long term credit for the implementation of some of the technologies and cropping patterns discussed in sections 6.3.4 and 6.3.5.

In addition to foreign source of financing, there may be scope for mobilizing domestic ones. Funding may come either from reallocating budget items (perhaps diverting expenditures from uses that are shown to have lower social and environmental benefits than the proposed ones). Or it may come through increases in revenues, linked to economic benefits generated by the proposed sustainable use measures.

In the case of the Sierra, some funding could come from a re-allocation of Veracruz State's budget. As discussed in detail in the GEF-PSSM study, the government of Veracruz has committed itself to raise funds for over $360m over the period 1996-2034 to foster the development of commercial plantations in the entire State . For areas, like the Sierra, with fragile ecosystems and limited entrepreneurial capacity, plantations development may be environmentally damaging[33] and socially inequitable[34]. Therefore, investment in small-scale agroforestry systems may be more appropriate.

Another option relates to the economic value of ecosystem services provided by the Sierra. About 70% of the water provided to the cities of Coatzacoalcos and Minatitlan (with a total population of over 400,000) comes from the Sierra. Land use change -induced soil erosion is leading to increasing sedimentation of water treatment plants, and possibly to a shortening of their average life.

Preliminary analysis contained in the GEF-PSSM study suggest that land uses that reduce sediment formation in the upper watershed may lead to savings[35] related to both sources of costs. It may be worthwhile reassessing the process of determination of water charges to

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[33] However, some studies (Parrotta, 1993; Lugo, Parrotta et al., 1993) suggest that carefully designed and managed plantations may help restoring degraded ecosystems, facilitate secondary succession, and foster species diversity.

[34] See (Paré, 1997) for a review of social issues related to plantations policies in Mexico.

[35] Savings from preventing a decrease in the plant's operating life may range between US$ 2m and 6m, and from lowering treatment costs may range between US$ 50,000 and US$ 230,000.

urban users, to ensure that they adequately reflect the full economic value of watershed services provided by the Sierra. The difference between "full cost" charges and current ones may be employed to support agroforestry, or other activities with beneficial impacts on soil conservation.

Annex 6-1: Estimating the demand for temporary work

The approach summarized by Equation 6-4 and Equation 6-5 can be applied in a straightforward way to labour regularly employed, by simply using census data on the number of regular workers as the denominator of y^L. The problem with non regular labour is that the number of workers is not a good indicator of actual input to production, as the actual time of work of a temporary employee varies widely across individuals, time of the year, and production sector.

A better indicator is the number of days of temporary work employed in production[36]. No data of this nature was available in the 1994 Economic Census; therefore, a broad order of magnitude for total days of non regular work employed in production was estimated on the basis of information from the 1990 General Census of Population and Housing (INEGI, 1991; INEGI, 1997).

The 1990 Census provides a breakdown, in classes of hours worked per week, of total employment in the municipalities under investigation. Assuming that services provided under temporary work arrangements do not exceed one third of a standard working week of 48 hours, only the classes 0 to 8, and 9 to 16 hours per week were considered. The mid point of these classes times total working weeks per year (43) divided by working hours per day (8) gives, for each class, average days worked per year.

[36] Days of work is also the unit of measurement of labour allocation decisions in the LP model of chapter 5.

The weighted average of days worked per year, with weights given by the share of workers in the total of the two classes of temporary employment, gives a figure of 43 days of work per year per temporary or non regular worker. Multiplying this number by the 1994 Economic Census figure on total non regular workers, we obtain an estimate of total number of days of temporary work in the trade, manufacture, mining and services industries sectors of the four municipalities considered as sources of temporary non-farm employment.

Annex 6-2 The income elasticity of cattle number demand

It is assumed that livestock product and hence cattle numbers are superior goods, and hence their elasticity grows with income. However, it is not plausible that consumption of livestock product increases without limits as income grows. One way to avoid this result is to assume that the share of livestock products in the food budget (or in the overall budget) grows initially, but then levels off to a plateau level, representing a "wealthy - status" level of meat and diary products consumption. Using a simple logistic growth function, the income elasticity η of cattle numbers must obey the following differential equation:

$$\frac{d\eta}{dY}=r\eta(Y)\left(1-\frac{\eta(Y)}{K}\right);\ \eta(Y_0)=\eta_0$$

Equation 6-8

where the r is the elasticity growth rate, K is the ceiling, or maximum level of elasticity, and Y is income, measured, as in section 6.2.2.1, by the value of total output of the trade, manufacture, mining and services industries in the four major municipalities of the region. The initial condition imposes that the at the beginning-of-simulation level of income, elasticity is equal to its postulated initial value, η_0, borrowed from (Barbier & Burgess, 1996)). The solution to Equation 6-8, which is the expression for the elasticity used in the model, is:

$$\eta_t=\frac{e^{rY_t}K\eta_0}{e^{rY_0}K+e^{rY_t}\eta_0-e^{rY_0}\eta_0}$$

The model uses a value of the maximum elasticity equal to three times the initial value; the rate of growth varies parametrically for use in scenario analysis, as discussed in section 6.2.4.

Annex 6-3 Pasture rotation

As discussed in chapter 2, basic analysis of pasture - driven frontier expansion explains deforestation in terms of nutrient mining: as nutrients decrease due to overgrazing, it is cheaper to convert new land to pasture than to invest in maintaining the productivity of existing pasture. However, as better quality land becomes scarcer, and/or property rights on land become better defined, ranchers may also consider pasture rotation schemes as a management option complementary to land clearance.

Figure 6-18 depicts the basic approach used in this model to address this possibility. If there is insufficient investment in management, a certain proportion of pasture is overgrazed and then abandoned. As time goes by, second growth vegetation will start to form on idle pasture, and nutrients will start to be stored.

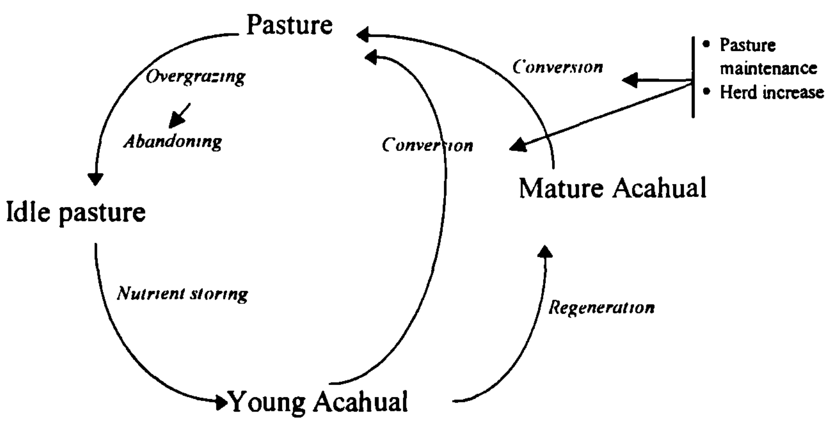

Figure 6-18 Pasture cycle

After some time, (2 to 4 years) idle pasture will turn into young *Acahual*; as the process of vegetation succession continues, woody species will tend to predominate over grassy ones, and young *Acahual* will turn into mature *Acahual* (after a period of say 5 to 10 years from the original pasture abandonment).

Both young and mature Acahual may be reconverted to pasture[37]. Conversion is motivated both by the need for replacing abandoned pasture, so that existing herds can be supported, and by the need for increasing herd size, when demand for livestock products increases.

If the demand for livestock products is constant or grows slowly, if overgrazing time is long, and if nutrient storing and vegetation regeneration time is short, the system could be in dynamic equilibrium: pasture and acahual land fluctuate around steady state values. However, in presence of growing demand for livestock, short overgrazing time, and long regeneration time, acahual tends to be depleted, and the pasture deficit will be met by conversion of primary forest.

In this model, the dynamics of pasture conversion and abandonment decisions revolves around variation in stocking rates (heads of cattle per hectare). For given cattle rearing and pasture management technology, there will be an optimal level of the stocking rate, s^*, which will vary across lands of different quality, slope, precipitation, and so forth. Ranches with rates below s^* are undergrazed, while ranches with rates in excess of s^* are overgrazed[38].

[37] It is plausible that land with better conditions of accessibility will be reconverted first, so that mature Acahual will be in worse location areas.

[38] Based on field evidence and existing literature (including the FAO report on livestock carried out in the context of the development of the GEF-PSSM study (Cervigni & Ramirez, 1997), an educated guess for "carrying capacity" stocking rate is of 0.75 and 1 heads/ ha for the buffer and influence zone, respectively.

The former have the potential of increasing herds without decreasing productivity, whereas in the latter nutrient exhaustion is bound to occur. The larger the stock of overgrazed pasture relative to the undergrazed one, the larger the need for converting land under vegetation cover, both for meeting increases in the demand for cattle numbers, and for replacing pasture eventually abandoned when nutrients are exhausted.

It then becomes important to estimate the percentage of overgrazed stock, and to determine its variation over time. For reasons of computation simplicity, it is assumed that stocking rates are distributed uniformly between a minimum and a maximum value[39]. The minimum value is constant, and equal to the minimum value obtained in the survey sample (0.15). The maximum varies over time, and is calculated using the expression of the average stocking rate $\bar{s}$, under the assumption of uniform distribution: $s_{max} = 2\ \bar{s} - s_{min}$.

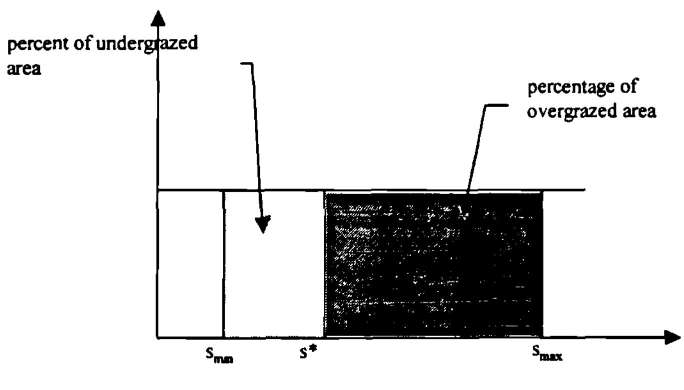

Figure 6-19 Distribution of stocking rates

As shown in Figure 6-19, the percentage of undergrazed pasture is the area, under the distribution of stocking rate, to the left of the carrying capacity s*, and is given by:

[39] Survey data, however, could have allowed use of more complex distribution, such as the normal.

$$p_{under} = \frac{s^* - s_{min}}{s_{max} - s_{min}}$$

so that the percentage of overgrazed pasture is 1 - p_{under} . If more cattle are purchased than pasture can support, nutrient exhaustion does not occur immediately, but after a given period of time , T_e (*Nutr_exhuast_time* in the model's terminology). Assuming that overgrazed pasture lands are distributed uniformly also across the range of times preceding exhaustion (0 - T_e), for every level of overgrazing maturity, overgrazed land will be:

*Overgrazing[Zone,Land_Type] = (1 - Percent_Undergrazed[Zone,Private]) * (Pasture[Zone,Private] - Idle_Pasture[Zone,Private]) / Nutr_exhaust_time*

The overgrazing flow adds to the stock of overgrazed land:

*Overgrazed_Pasture[Zone,Private](t) = Overgrazed_Pasture[Zone,Private](t - dt) + (Overgrazing[Zone,Private] - Pasture_depletion[Zone,Private]) * dt*

After T_e years, overgrazed land is depleted of nutrients and abandoned. Abandoned land flows in the Idle Pasture reservoir:

*Idle_Pasture[Zone,Land_Type](t) = Idle_Pasture[Zone,Land_Type](t - dt) + (Abandoning[Zone,Land_Type] - Initial_succession[Zone,Land_Type]) * dt*

The earlier stage of the succession process (*Initial_succession*) last a certain number of years (*Nutrient_storing_time*), after which idle land turns into young acahual:

*Young_Acahual[Zone,Land_Type](t) = Young_Acahual[Zone,Land_Type](t - dt) + (Initial_succession[Zone,Land_Type] - Acahual_regeneration[Zone,Land_Type] - Conversion_ Young_Acahual_pasture[Zone,Land_Type]) * dt*

Land flows out of this stock either through formation of mature acahual (after a regeneration time T_r, *Acahual_regeneration_time* in the model's terminology), or via conversion to pasture. In particular, there will be a fraction of Young Acahual that is converted to pasture:

Conversion_Young_Acahual_pasture[Zone,Land_Type] = LEAKAGE OUTFLOW; LEAKAGE FRACTION = Min(1, (Demand_for_pasture[Zone,Land_Type]/Max(1, Young_Acahual[Zone,Land_Type])))

The fraction is given by the ratio between the demand for pasture and the stock of Young Acahual, if this is less than one; if it is larger than one, all the existing stock will be converted to pasture, and the difference will be made up for by the existing mature acahual:

Conversion_acahual_to_pasture[Zone,Land_Type] = IF(Acahual[Zone,Private]>0) then (Demand_for_pasture[Zone,Land_Type] - Conversion_Young_Acahual_pasture[Zone,Land_Type]) else 0

7. Conclusions and directions for future research

This dissertation has defined the biodiversity problem, explored in theory and in practice the causes of land use change, and discussed policy and management options for supporting the conservation and sustainable use of biodiversity through mobilization of local, national, and international resources. This final chapter draws some brief conclusions, and suggests directions for future research.

7.1. Land use and biodiversity management: policy implications

A first point regards the analysis of the process of loss. In the same way that there is no single explanation for development, there is no single explanation for land use change, and there is no single strategy for mitigating the adverse impacts of land use change on biodiversity.

The Mexico case study has documented that multiple factors collude in determining pressure on forest margins, vegetation cover, and resource extraction; these factors include income growth, tenure, access to outputs and credit markets. Some factors may have ambiguous impacts: income growth, for example, both alleviates land pressures related to subsistence farming, and increases conversion to pasture via increasing demand for livestock products.

Because of these ambiguous impacts, and because the relative significance of other factors varies according to the initial conditions and the historical evolution of social and economic systems, there is a clear need for micro-level analysis of the causation process. These may provide local and national decision makers with situation-specific policy indications to address a problem that is, by nature, location specific: any given ecosystem of particular significance in terms of its genetic, species and community diversity exist in a well-defined geographical location. Basing policy decisions on averages of effects across locations may not be appropriate, if the objective is to conserve individual ecosystems, and not their net sum.

A second point concerns the definition of the biodiversity problem. Biodiversity loss is sometimes portrayed as the inevitable consequence of conflicting interests between national development objectives of countries in the south of the world, and conservation objectives of developed countries. This conflict arises primarily if a) biodiversity objectives are defined in terms of full conservation; and b) if the services provided by diverse ecosystems fail to be recognised and valued by local policy makers and resource users.

If one accepts the view that biodiversity and ecosystem services may be maintained not only through preserving wilderness areas, but also through appropriate management of the productive landscape, then a wide range of opportunities opens up, for resolving conflicts among stakeholders in developing countries, and for establishing partnerships between developing and developed countries. Support form the international community needs not be the only solution to the biodiversity problem (Perrings, Mäler, Folke, Holling, and Jansson, 1994).

This leads to the third point, concerning funding. The distribution of the cost of conserving biodiversity between local, national and international stakeholders can not do without a) acceptance, by the various stakeholder, of biodiversity objectives, and of a biodiversity management strategy; b) understanding of the causes of loss c) identification of individually incentive compatible alternatives.

If resources are to be used efficiently, the design of a funding strategy needs to recognise, and take advantage of, social and private incentives, at the local level, to implement management options that lead to sustainable use of natural resources and biodiversity. The best use of biodiversity-targeted funding (such as the GEF) may be to generate catalytic effects and encourage access to other sources of finance, both nationally and internationally.

7.2. Directions for future research

Inspection of the literature suggests that the interactions between social and economic systems on the one hand, and ecosystem functioning and health on the other, are poorly understood (Perrings, Mäler, Folke, Holling, and Jansson, 1994; Barbier, Burgess, and Folke, 1994; Costanza, 1991; Perrings & Pearce, 1994). This defines a broad agenda for future research.

The call for national and international actions to correct market, government and institutional failures in the management of biodiversity, is justified by the argument that by preserving adequate levels of the diversity traits of natural systems, human welfare can be sustained in a lasting manner.

At the same time, there is no definitive understanding of: a) the relationship between human activities and diversity; and b)· the relationship between diversity and welfare generating properties of natural systems. As a result, the management implications of the generic call for biodiversity conservation are far from clear. There are several important parameters affecting relevant decision making processes.

These are related, among others, to discounting (i.e. trading off present versus future welfare), local and international conservation preferences, infra-national and international redistribution parameters, probabilistic structures relating human activities to welfare via their impact on diversity. Depending on assumptions made about those parameters, alternative management options of natural and semi-natural systems can be justified.

At the policy level, recent studies of international agencies (e.g. (World Bank, 1996) (Srivastava, Smith, and Forno, 1996; Smith, 1996) as well as recent decisions of the Conference of the Parties (COP) of the Biodiversity Convention suggest that international policy makers are increasingly moving away from traditional paradigms of conservation based on the maintenance of large, undisturbed protected areas. Indeed, COP's emphasis on sustainable use and agrobiodiversity suggest that increasing importance for the biodiversity cause is being attached to management options that entail various degree of natural habitats' modification.

In the extreme, one can argue that in fact any management option can be justified ex post by an appropriate choice of parameters reflecting underlying probabilistic and value judgement assumptions. If this was the case, policy and management decisions would be the result of an essentially political process, where proponents of alternative course of actions would try to influence decision makers through a partisan use of the scarce information available.

This state of affairs suggest that there are still important roles applied research can play. First, it can reduce the uncertainty surrounding preferences, probabilities and other key parameters of the decision making problem. Second, even when information on the decision parameters is not yet available, applied research can elucidate the terms of some critical trade offs. For instance, it can clarify the social and economic processes whereby human activities modify ecosystems and presumably their diversity. In the same way, applied research can shed some light on the impact of alternative management options on natural systems, and on their social and economic costs and benefits.

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