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Chile
Managing Environmental Problems: Economic Analysis of Selected Issues

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CURRENCY EQUIVALENTS

Currency Unit - Chilean Peso (Ch$)

Average 1992: US$1 = Ch$363
Average 1993: US$1 = Ch$404
April 1994: US$1 = Ch$424

WEIGHTS AND MEASURES

Metric System

FISCAL YEAR

January 1 to December 31

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CHILE - MANAGING ENVIRONMENTAL PROBLEMS: ECONOMIC ANALYSIS OF SELECTED ISSUES

ABSTRACT

Chile's main environmental issues are: (a) urban pollution of air and water; (b) industrial pollution by localized industries, in particular mining; and (c) the intensive use of natural resources, including native forests and fisheries. This report provides an overview of environmental problems in Chile and outlines elements of an environmental strategy. The detailed chapters on air and water contamination in Santiago, and native forest management in a case study area go well beyond the description of problems and provide an in-depth analysis of three serious problems as examples for the application of economic analysis to environmental issues.

This report recommends integrated environmental management based on the comparison of costs and benefits. A delay of improved environmental management would create high costs in the future, and could potentially limit access to foreign markets. The government should focus its resources on priority areas, set realistic objectives, and enforce the regulations enacted to achieve these objectives. Priority should be given to instruments, such as presumptive charges or performance bonds, that shift the administrative burden to the polluter.

Water Pollution is due to the lack of adequate treatment of domestic and industrial wastes. Irrigation with sewage polluted water causes health risks, particularly in the SMR.

- A strategic long-term plan for water quality management in the Maipo-Mapocho Basin should be developed and implemented to address the construction of municipal wastewater treatment plants and the implementation of policies to control industrial discharges.

- An effective industrial discharge control program should include: (a) a discharge registry and permit system; (b) application of economic instruments and incentives such as a sewer use fee for industries; (c) implementation of self-reporting and certification systems for private auditing firms; and (d) a system of spot checks of the self-reporting program.

- Water quality management should be integrated into the broader framework of water resource management. Changes in the legal framework should include the option to link water usage rights to a specified level of water quality.

- Priority should be given to developing a strong institution for overall management of surface and ground water and of quality control. Better coordination, through water basin corporations, for control of water pollution at source is needed.

- Implementation of water quality policies, monitoring and studies should be decentralized to the regional or basin level. In the future, these responsibilities could pass to the regional environmental commissions or to proposed river basin corporations.

Main sources of air pollution in Santiago are industrial and vehicle emissions as well as road dust. Air pollution leads to measurable health damages including premature deaths.

- Several pollution control measures already under implementation and additional options for PM-10 reduction can be justified on the basis of health benefits alone. In the medium term, a focus of air pollution control strategies on PM-10 reductions is justified.

- The PM-10 compensation mechanism for fixed sources in Santiago can potentially improve air quality in a cost-effective manner, but several design and implementation details need to be improved and strict enforcement needs to be ensured.

- Diesel truck and gasoline vehicle emission standards, conversion of buses to natural gas, and conversion of wood burning industries to other fuels are economically attractive options for reducing PM-10 emissions with benfits-cost ratios between 1.2 and 2.4.

- The analyzed PM-10 emission controls produce about US$70 million in health benefits, equivalent to US$18,000 per emitted ton reduced. Thus, controls reducing PM-10 emissions at a cost below US$18,000 per ton should be considered worthwhile.

- General energy price increases, as well as increased user charges for wood-fuel and electricity can deliver PM-10 emission reductions. Similarly, fuel taxes, differentiated by emission levels, would create economic incentives for emission reductions.

- Additional analysis is needed on the behavior of and control strategies for road dust. Road dust could represent quantitatively important and cost-effective control opportunities.

<u>Native Forests</u> are valued for their biodiversity but are currently being depleted rapidly for fuelwood and raw material for woodchips.

- Biodiversity protection goals will not be met by relying on market forces, and additional areas should be protected to preserve all major representative flora and fauna. Priorities for protection areas should be identified by expert groups. The introduction of tradable development options could help insure that protection needs are met at least-cost.

- Markets also fail to capture the substantial landscape value in certain forested hillsides behind lakes and recreational areas. As with biodiversity, intervention will be required.

- The use of remaining forested areas that are not important providers of external benefits could be determined by market forces. Study findings indicate that the difference in present value between managed native forests and plantation alternatives may be as much as 100 percent or US$2,000-2,500 per ha. at a 10 percent discount rate.

- Currently, a large share of the depletion of native forest occurs in violation of existing regulations. A conscious political decision needs to be made with respect to how much and which native forests to conserve. This decision should then be strictly enforced.

- Research should analyze the potential of native forest management techniques that retain the ecological value of the forest but also provide adequate financial returns. Options for creating economic incentives for native forest management should be studied.

ABBREVIATIONS

BOD	Biochemical Oxygen Demand
CEDRM	Special Commission for Decontamination of the Metropolitan Region (Comisión Especial de Descontaminación de la Región Metropolitana)
CFC	Chlorofluorocarbon
CNE	National Energy Commission (Comisión Nacional de Energía)
CODELCO	National Copper Corporation (Corporación del Cobre)
CONAF	National Forestry Corporation (Corporación Nacional Forestal)
CONAMA	National Environmental Commission (Comisión Nacional del Medio Ambiente)
COREMA	Regional Environmental Commission (Comisión Regional del Medio Ambiente)
DGA	Water Department of the Ministry of Public Works (Dirección General de Aguas)
DNR	Department of Irrigation (Dirección Nacional de Riego)
EIA	Environmental Impact Assessment
EMOS	Santiago Water Utility (Empresa Metropolitana de Obras Sanitarias)
ENAMI	National Mining Company (Empresa Nacional de Minería)
ESVAL	Valparaiso Water Utility (Empresa de Obras Sanitarias de Valparaíso)
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GNP	Gross National Product
GTZ	German Development Agency
IBRD	International Bank for Reconstruction and Development
IDB	Inter-American Development Bank
MIDEPLAN	Planning and Cooperation Ministry (Ministerio de Planificación y Cooperación)
MOH	Ministry of Health
MOP	Minstry of Public Works
NAFTA	North-American Free Trade Agreement
NPV	Net Present Value
PM	Particulate Matter
PM-10	Particulate Matter (less than 10 micron in diameter)
PPP	Purchasing Power Parity
RAD	Restricted Activity Days

SAG	Agriculture and Livestock Service of the Ministry of Agriculture (Servicio Agrícola y Ganadero)
SMR	Santiago Metropolitan Region
SEREMI	Secretariat of Regional Ministers (Secretaría Regional Ministerial)
SESMA	Environmental Health Service of the Metropolitan Region (Servicio de Salud del Ambiente Región Metropolitana)
SNASPE	National System of Protected Areas (Sistema Nacional de Areas Silvestres Protegidas del Estado)
SSA	Environmental Health Service of the Ministry of Health (Service de Salud Ambiental)
SSS	Sanitary Service Superintendency (Superintendencia de Servicios Sanitarios)
TSP	Total Suspended Particles
UNDP	United Nations Development Program
USAID	United States Agency for International Development
VOC	Volatile Organic Compounds
WHO	World Health Organization
WTP	Willingness to Pay

This report was prepared by a World Bank team consisting of Joachim von Amsberg (Chapters I and V), Carl Bartone (Chapter II), Gunnar S. Eskeland (Chapter III), and John A. Dixon (Chapter IV). Earlier missions for the preparation of this report were led by Paul Levy and Denise Williamson. The report was completed under the guidance of Danny M. Leipziger (Lead Economist) and was edited with the assistance of William Mayville. Secretarial assistance was provided by Suchila Burns and Mina Kennedy. Peer reviewers were William Magrath, Alberto Valdes, and David Wheeler. The report is based on field work completed in 1993 and takes into account comments received during discussions with the Government in September 1994 and during a policy seminar in Santiago in November 1994.

The report is based on background studies by the following authors (detailed references to these studies are provided at the end of the report):

Water: Catterina Ferreccio, Ricardo Katz, Maria Benitez, Francisco Brzovic, Jose Miguel Sanchez, and Juan Antonio Poblete.

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EXECUTIVE SUMMARY

A. Background

1. Chile has experienced a period of strong economic growth. As growth has proceeded at a rapid pace, the health and productivity costs of environmental degradation have become apparent. Chile's main environmental issues are: (a) urban pollution of air and water; (b) industrial pollution by localized industries, in particular mining; and (c) the intensive use of natural resources, including native forests and fisheries. The importance of environmental problems is highlighted by the tremendous economic role of those sectors that are associated with the use of renewable resources (agriculture, forestry, and fisheries), and industrial pollution (mining).

2. The purpose of this report is threefold. First, it provides an overview of environmental problems in Chile and outlines elements of an environmental strategy. Second, the detailed chapters on air and water contamination in Santiago, and native forest management in a case study area (Region X) go beyond the description of problems and provide an in-depth economic analysis of three serious environmental issues. Third, the three studies of discrete environmental problems show how the tools of economic analysis can be used to analyze complex environmental issues, employing methodologies that can also be applied to other environmental problems not analyzed in detail in this report.

3. This report demonstrates that Chile's growth has had significant environmental implications. The exploitation of natural resources has led to investments, for example in forest plantations, but also to the depletion of resource stocks, for example the native forests. This report attempts to apply systematic economic analysis to environmental problems for determining efficient environmental policies and selecting policy and investment options that improve environmental quality. It is shown how these efficient environmental policies can reconcile the objectives of economic development and environmental protection and increase overall welfare in the economy.

B. Environmental Policy and Strategy

4. Principles of an Environmental Strategy. This report recommends integrated environmental management based on the comparison of costs and benefits. In the past, the costs and benefits of using environmental resources have been assessed in isolation from each other, leading to fragmented and contradictory policies. On the one

hand, policies that ignored the costs of environmental degradation have led to unnecessarily large environmental costs. On the other hand, environmental policies determined without regard for the costs of environmental protection were often unrealistic and left unenforced. In contrast to past practice, integrated environmental management is based on a conscious decision about the use of the country's environmental resources. A successful environmental strategy will be forward looking. A delay of improved environmental management would create unnecessarily high costs in the future, and could potentially limit access to foreign markets.

5. The main strategy for achieving integrated environmental management is to let the prices of all goods reflect their full social costs, including environmental damages. If the full social cost is charged for every activity that degrades the environment or the resource base, economic decisions in all sectors will take environmental considerations into account, and environmental protection can be achieved at a lower cost. Fortunately, Chile's economy is free of gross prices distortions through subsidies on environmentally harmful activities. Also, Chile's focus on strong property rights, including some natural resources, helps move prices closer to full social costs. However, like in most other countries, the prices of most goods do not yet include their environmental costs. The challenge remains to establish efficient environmental policies that internalize environmental costs and, where feasible, extend property rights to environmental goods.

6. Environmental Policy and Institutions. The government is now seriously committed to addressing environmental problems. While environmental regulations have existed for some time, they were fragmented and based on the perspective of individual sectors without coordination or effective enforcement. In an attempt to bring a systematic approach to complex environmental regulations, the parliament passed, in early 1994, the Law about the General Basis for the Environment (Basic Law). The passing of this law is an important milestone for setting the framework for environmental management in Chile. The Basic Law also defines the role of the National Commission for the Environment (CONAMA) as the national environmental agency to coordinate and implement environmental policies, strategies, and action plans.

7. The passing of the Basic Law provides an important opportunity for further advances on the transition from sectorally fragmented environmental management to an integrated approach, coordinated by CONAMA. In practice, however, CONAMA will face an extremely difficult task over the next few years in asserting and fulfilling its new responsibilities and creating consistency in the regulatory body. At this stage, CONAMA and its regional commissions (the COREMAs), do not have the capacity to adequately meet the responsibilities assigned to them by the law. Bottlenecks are expected specifically in the administration of the Environmental Impact Assessment (EIA) process that has now become mandatory for all major investment projects. In addition, there is

an urgent need to improve the availability of environmental information and the capacity for systematic analysis of environmental problems.

8. The next few years will prove to be critical for the credibility of an improved approach to environmental management under the Basic Law and the new institutional framework. In this difficult development period, CONAMA should focus its resources on priority areas where it has the capacity to achieve progress. Realistic objectives should be set, and the regulations enacted to achieve these objectives must be effectively enforced. The expectation that future international trade agreements will require compliance with national environmental standards points to the importance of realistic but effectively enforced national environmental regulations.

9. Instruments. Implementation of an environmental strategy will rely on a variety of instruments depending on the specific problem, including standards, environmental taxes, and tradeable rights. With its strong emphasis on free markets and private property rights and a strong legal system, Chile is better positioned than many other countries to develop market-based approaches to environmental management. Hence, the focus of environmental policy should be on market-based instruments wherever they are feasible and cost-effective. Given the weakness of some enforcement institutions, priority should be given to instruments that shift the administrative burden to the polluter. In cases such as hazardous waste, liquid effluent disposal or compliance with forest management plans, presumptive charges or performance bonds, could be an attractive instrument. With these instruments, charges are assessed on the basis of the worst possible damage unless the polluter credibly demonstrates lesser damage.

10. Trends. Where environmental quality directly affects human welfare, higher income tends to be associated with less environmental degradation. On the other hand, where the costs of environmental damage can be externalized, economic growth will result in a steady deterioration of the environment. Problems of fuelwood gathering, indoor air pollution, insufficient sanitation, and unsustainable farming methods are likely to decline with increasing investment. In the case of air, water, and soil pollution, however, there are no markets for environmental quality and the increase in demand for environmental services does not directly translate into environmental improvements. The increasing demand for environmental quality can only be satisfied through tighter environmental regulation or the creation of markets for environmental goods where they are feasible.

11. Policy Priorities. The detailed studies of air and water pollution as well as native forest management in this report address three of the most important environmental problems Chile faces today. There are other environmental problems that require detailed analysis with similar methodologies including pollution from the mining sector, management options for toxic and hazardous wastes, as well as policy options for choosing energy sources and promoting energy use efficiency. The present report only

provides a summary of these issues without analyzing the problems in detail. Studies in these areas should be carried out by the responsible sector agency with coordination by CONAMA.

12. A major environmental issue that is not analyzed in detail in this report is mining sector pollution. The mining sector plays a key role in the Chilean economy but is also the largest source of industrial pollution (primarily sulfur dioxide, particulates, arsenic, and metallic residues). The government's approach to alleviate mining sector pollution focusses on Environmental Impact Assessments (EIA) for new projects and decontamination plans for existing installations. New investments are now required to undergo a systematic EIA. As a result of this requirement and the use of cleaner technologies that meet common international environmental standards, new projects cause significantly less environmental damage, and safeguards to control the environmental effects of the expected rapid future expansion in the sector are in place.

13. With regard to existing mining operations, a 1992 decree requires the implementation of decontamination plans. These plans apply, among others, to the existing smelters of the state mining enterprises, which are among the worst polluters of the country. Under the decontamination plans, compliance with ambient standards will be achieved by 1999. The total cost of implementing the decontamination plans in the state mining companies are estimated to reach US$1 billion. Economic analysis should be undertaken for additional emission reduction measures at mines and smelters. Studies of the potentially significant environmental impact of small-scale mining are also required. The development of a realistic policy to address arsenic emissions should have priority.

14. The development of a strategy for the management of toxic and hazardous waste should be given high priority. Currently, information is very limited and incentives for the proper disposal of hazardous substances are low. Preemptive charges may be an attractive policy option to prevent illegal dumping resulting from higher fees for the proper disposal of industrial wastes.

15. Energy Sector. The increasing environmental costs of expanding electricity generation, can be reduced by including nontraditional renewable energy sources (wind and solar) and encouraging increased energy use efficiency through demand-side management policies. The evaluation of energy policies should include the environmental cost of different options. Environmental taxes differentiated by fuel type could be used to internalize environmental costs in the energy sector and create efficient incentives to electricity producers and consumers.

16. Fisheries. The commercially most important fisheries are in a situation of full exploitation. Given the natural volatility of some species, the uncertainties about stock size, reproduction, and interactions between different species, the current situation implies significant risks that can be reduced by improving data and scientific understanding of the

fisheries, and by increasing the administrative capacity for managing the resources. Within a set of different instruments for the management of the fisheries, a broader use of individual transferable quota should be reconsidered, carefully taking the limitations of this management instrument into account.

17. International Environmental Issues. As environmental problems associated with high consumption level begin to supersede those associated with poverty, Chile's contribution to global environmental problems, such as global warming, will become more important. Even though, in the short-term, it is not in Chile's narrowly defined national interest to spend own resources on measures to reduce global environmental externalities, it can be expected that future international agreements will increasingly lead to the internalization of global environmental costs. The future costs of complying with such agreements can be reduced through preemptive policies for reducing global environmental externalities such as measures to increase energy use efficiency.

18. Short-term Priorities. Given limited resources for implementing efficient environmental management, there is a need to establish priorities for action. Based on the analysis in this report, priority areas for action are those where: (a) the reversal of environmental damages is impossible or particularly costly. This would apply to the protection of native forests, since large tracts of native forests are currently depleted; (b) the ratio of expected benefits to costs is particularly high. This applies to several measures improving air quality in the Santiago Metropolitan Region; and (c) large investments are expected to be made in the near future, which presents a cost effective opportunity for implementing environmental protection measures in the design of new facilities. This applies particularly to the mining sector and the municipal wastewater sector, where publicly owned utilities are required to undertake major treatment investments. In each case, it would be desirable to improve the information base for determining efficient policies. However, immediate steps can already be taken based on an analysis of the existing information.

C. Water Pollution in Santiago

19. Water pollution in most areas of the country is due to lack of adequate treatment for domestic and industrial effluent. Polluted rivers also contaminate coastal areas. Even though sanitation services in Chile are well developed, the disposal of collected waste water is inadequate. Biological pollution of waters and resulting diseases are common. Information on the level of industrial pollution of waterways is limited. So far, no unified water management policy has emerged and responsibility for water resource management is fragmented and overlapping.

20. Purpose of the Study. Surface water resources in the Maipo-Mapocho valley, which are heavily polluted by both domestic and industrial wastewaters from the Santiago Metropolitan Region (SMR), are used to irrigate about 130,000 ha -- including

some 7,000 ha used for growing vegetable crops for raw consumption in the immediate vicinity of Santiago -- resulting in atypically high rates of typhoid and hepatitis and, more recently, on outbreak of cholera. Endemic typhoid is not recent, but has persisted for decades without decisive action being taken. The appearance of cholera gave a new sense of urgency and purpose to attempts to enforce regulations that have been on the books for years but never seriously enforced. Emergency measures taken in 1991 succeeded in controlling the spread of cholera and, coincidentally, in reducing levels of endemic typhoid. These measures now need to be consolidated.

21. The present study seeks to contribute to a broader view of these issues and help inform the debate now underway about wastewater treatment in Chile that was prompted by the cholera threat. The focus of this study is exclusively on the health impact of microbiological water pollution in the SMR. It seeks to identify the most relevant policy option(s) for consolidating cholera and typhoid control and to determine if the costs can, in fact, be justified in whole or in part on the basis of expected direct and indirect health benefits. In addition to estimating the health costs and benefits of different policy options, the study also examined the existing regulatory and institutional framework for water quality management in relation to the policy options.

22. Health Impacts of Water Pollution in Santiago. Epidemiological analysis shows that endemic typhoid in the SMR was causally linked to the practice of vegetable irrigation with sewage polluted waters, which was responsible for about three-fourths of the cases. The emergency measures imposed in 1991 succeeded in reducing typhoid and preventing the spread of cholera by interrupting the long cycle mechanism of transmission, mainly through changes in the population's vegetable consumption patterns and in irrigation practice. The stability of these changes is difficult to predict.

23. Typhoid morbidity impacts were estimated using cost of illness analysis for the combined treatment costs and productivity (labor wage) losses from 1985-90. During the same period, the losses due to typhoid mortality were estimated by the human capital approach. The total direct health costs were on the order of US$1.4 million per year for typhoid. In the event of no action, the potential direct health costs of a cholera outbreak obtained by extrapolating from the typhoid model could have been as great as US$14.7 million in 1991. Even if just an order of magnitude estimate, it is clear that the health, social, political and economic risks of cholera are great and demand action.

24. Agricultural exports for human consumption have grown steady over the past decade (except for 1989) representing 12-13 percent of total exports in recent years with a value in excess of US$1.1 billion, of which fruit exports account for more than 85 percent. The SMR produces almost 40 percent of the total exportable fruit in Chile. A cholera epidemic centered in the fruit growing center of the country could lead to significant losses, as happened previously in Israel and Peru. Extrapolating from a recent

incident involving Chilean grapes, the minimum potential losses are estimated to be on the order of 5 percent of fruit exports, or about US$50 million.

25. Full wastewater treatment that will meet Chilean water quality standards for unrestricted irrigation, which is considered the only risk-free, long-term barrier to typhoid and cholera, will cost on the order of US$78 million per year. The continuation of the emergency measures implemented in mid-1991 (principally field inspections of crops and public education campaigns) will cost on the order of US$1.6 million per year, but the long-term effectiveness of these measures is in doubt. Other measures are unfeasible or simply not an alternative to full treatment

26. The farm level impact of the emergency measures are significant. Losses to farmers are not equally distributed, but could amount to US$4.9 million per year due to reduction in irrigation volumes and areas and the loss of fertilizer value of wastewater. On the other hand, the introduction of full treatment would allow many farmers to return to cultivation of higher-value crops with an estimated benefit of US$6.4 million per year. Supply and demand were also affected by the emergency measures. The cultivation of 12 prohibited vegetable crops in the SMR has been reduced in area by 30 percent, leading to price increases of between 75 and 100 percent. Estimates of increased consumer costs for these vegetables are on the order of US$7.2 million per year.

27. This study in the SMR (Maipo-Mapocho Basin) points to a number of weaknesses in the existing regulatory and institutional framework for water quality management:

a. the present Water Code fails to deal adequately with water quality issues, ignoring fundamental linkages between water quantity and quality, and failing to define a framework for managing relations between water uses and users;

b. there are many institutions involved in managing water quality, in many cases with overlapping responsibilities and inadequate mechanisms of coordination -- evidenced by the water pollution levels observed in spite of the attention paid to this issue;

c. notwithstanding the great effort made to develop a water market, transactions are rare, a significant amount of water rights are held for speculative purposes, and the lack of depth of water markets undermines potential transactions for reclaimed wastewater; and

d. industrial discharges are likely to limit wastewater reuse and cause other water pollution problems in the future unless effective control policies are promulgated by the Superintendencia de Servicios

Sanitarios (SSS) and implemented by Santiago's water utility, EMOS, and the industrial sector.

28. The principal study conclusion is that the quantifiable health related benefits (and gains to farmers and consumers) would offset treatment costs by from one-third to fully, depending on the assumptions made about the probability of a cholera epidemic occurring under present conditions. Considering that there are significant additional non-health benefits related to wastewater treatment, along with evidence of an opportunity cost of water nearly equivalent to the cost of treatment, it is not surprising that many metropolitan and national policy makers now view wastewater treatment as a necessary and viable environmental infrastructure investment.

Recommendations

29. The emergency measures to prevent the spread of cholera, while successful, are at best short-term actions in response to an immediate health priority. A strategic long-term plan for water quality management in the Maipo-Mapocho Basin should be developed and implemented to address the following concerns: (a) construction of municipal wastewater treatment plants to provide full protection from pathogens and enable safe reuse; (b) implementation of policies to control industrial discharges in the SMR; and (c) establishment of adequate control systems for industrial discharges. The strategic plan should be reviewed and adjusted every 3-5 years in response to changing conditions. The ongoing EMOS study to define wastewater treatment options will be completed in late 1994 and should receive priority attention from the administration.

30. For an effective industrial discharge control program, greater attention should be given to the coordinated actions by SSS and EMOS or other sewerage companies, including: (a) creation of a discharge registry and permit system that can be continually updated; (b) application of economic instruments and incentives; (c) assistance to industries for implementing self-reporting requirements, and develop a certification program for private auditing firms; (d) development of the capacity to supervise and provide spot checks on the self-reporting program and verify that pretreatment requirements are met prior to discharge to municipal sewers; and (e) establishment of sewer use fees to industries based on volume and load of each industry's effluents, set to ensure that industries pay their fair share of the investment and operating costs of municipal sewerage and treatment systems.

31. The time is ripe to address a number of issues related to the integration of water quality management into the broader framework. While the present Water Code virtually ignores quality issues, proposed modifications to the Water Code could, in combination with the new Basic Law, create new institutional structures to deal with combined water quantity-quality problems. It is important to ensure consistency and complementarity between these legislative measures. Proposals for consideration should

include the option to link water usage rights to a specified level of water quality. This would give water right holders the opportunity to fight infringements of their rights (i.e. pollution of the water body) directly through the legal system.

32. Priority should be given to developing a strong institution for overall management of surface and ground water and of quality control. The Direccion General de Aguas (DGA) is the natural rector institution for integrated management of water quantity and quality, and its powers and resources should be examined to determine if they are adequate for the job. Better coordination, through water basin corporations, for control of water pollution at source is needed between DGA and the Servicio de Salud Ambiental (SSA), and with SSS, EMOS and the Servicio Agricola y Ganadero (SAG). In the area of water quality management, CONAMA should work closely with DGA to ensure that water quality issues are effectively integrated into the overall regulatory and institutional framework for water resources.

33. Implementation of water quality policies, monitoring and studies should be decentralized to the regional or basin level. In the future, these responsibilities could pass to the regional environmental commissions (eg, CEDRM) or to proposed river basin corporations. The latter proposal seems the most sensible -- to have water quality treated as an integral part of basin-wide water development along with other intersectoral issues. At the level of the Maipo-Mapocho Basin, CEDRM should actively assist DGA in defining and setting up a basin corporation.

34. At present there is no way to impute an environmental value for the quality of water resources. Consideration should be given to the application of effluent charges which would stimulate willingness to pay for wastewater treatment and could provide a means of raising revenues for water quality management programs. Such a measure would help overcome political reluctance to invest in municipal wastewater treatment because of the corresponding water tariff increases mandated by the Sanitary Code.

35. Beyond the present analysis of microbiological water pollution, a more comprehensive evaluation of the health effects of different forms of water pollution would be desirable. This includes the analysis of possible contamination of the food chain from toxic water pollution, a socio-economic analysis of the affected population, and attention to hygiene education and other long-term preventive measures.

D. Air Pollution Control in Santiago

36. Santiago experiences very high levels of air pollution, in many instances substantially exceeding guidelines suggested by the World Health Organization. Air pollution in Santiago causes significant health damage, including premature death and serious respiratory diseases. Air pollution in Santiago is caused by industrial and vehicle emissions as well as street dust blown from unpaved roads and eroded hillsides, and is

aggravated by thermic inversion and the city's location in an enclosed valley. The decontamination measures taken over the last years have so far been insufficient to lead to a significant improvement in air quality. However, the decline of air quality has been arrested despite increasing population and industrial activity. Analysis of industrial pollution problems has been hampered by lack of information as well as conflicting institutional responsibilities.

37. This report contains a cost-benefit analysis of several proposed control options including the following components: (a) the development of a control strategy, with quantification of its costs and effects on emissions of the various air pollutants; (b) a dispersion model to simulate the effects that the emission reductions of the *Control Strategy* would entail in terms of improved air quality, particularly in highly populated and highly polluted areas; (c) a model for health effects of air quality improvements to estimate the improvements in public health that such air quality improvements are likely to deliver in Santiago; (d) a tentative valuation of health effects in terms of work-day equivalents, and finally; (e) a cost benefit comparison.

38. This study estimates the improvements in public health that could be delivered by a realistic package of emission control initiatives. The study applies a set of modules in its analysis, each of which lays out both the technical background and the assumptions. While there are remaining uncertainties, the study breaks new ground in several areas: a multipollutant perspective; a decision-making perspective with realistic alternatives; a dispersion model that estimated effectiveness of emission reductions and exposure reductions; and the evaluation of a broad range of health effects.

39. In terms of costs and benefits, the analysis indicates that a very modest valuation of health effects is *sufficient by itself* to justify control efforts in the range of US$50-100 million, even when such a control strategy is not carefully optimized. The health *valuation* is conservative, since it accounts only for lost productivity and treatment costs. The *estimation* of health effects is also conservative, since the study includes only acute effects, while suspected cumulative and long-term effects are not included. Clearly, if non-health benefits of air pollution improvements were included, the benefit estimate would be increased further.

40. The study points in the direction of attractive investment proposals. The conclusion of the study is to proceed with the formulation and implementation of policies that make emission reductions attractive to polluters. If such policies allow maximum *relevant* flexibility to polluters, then emission reductions and the subsequent health improvements are likely to come at much lower costs than those suggested by this study. In terms of the location of emission reductions, the study indicates that vehicular control strategies are more effective in reducing concentrations in the high-exposure downtown areas than are strategies for fixed sources. This is a conclusion that feeds directly into the challenging design issues of a tradeable permit program.

41. In terms of research, the study has contributed with a dose response estimation for Santiago, which indicates that both mortality and morbidity responds to air pollution in Chile, lending support to the application of dose response functions from elsewhere when locally estimated functions are not available. Epidemiological research in Chile has pointed to these effects earlier, and more research is ongoing locally.

Recommendations

42. The high level of air pollution in the Santiago Region causes measurable and significant health costs. The reduction of one ton of PM-10 emissions (particles less than 10 microns in diameter, sufficiently small to penetrate deep into the lungs) yields health benefits more than ten times as high as health benefits from the reduction of other pollutants. Beyond pollution control measures currently under implementation, additional cost-effective options for PM-10 reduction are available, and, in the medium term, a focus of air pollution control strategies on PM-10 is justified.

43. The reduction of one ton of PM-10 emissions from each broad group of emitters, such as fixed sources, buses, cars and trucks, has about the same effect in terms of reducing PM-10 exposure. Thus, in an efficient pollution control strategy, the marginal control costs per ton of emission reduction should be roughly equal across these groups of emitters. Several analyzed strategies for reducing PM-10 emissions are economically attractive and yield benefits in the order of 1.2 to 2.4 times the control costs (including diesel truck emission standards, conversion of buses to natural gas, and conversion of wood burning industries to oil or gas). Even though the costs of gasoline vehicle emission controls are high per ton of reduced PM-10 emission, additional gains in ozone reduction make such controls attractive, with a benefit-cost ratio of 2.4.

44. The PM-10 compensation mechanism for fixed sources in Santiago can potentially improve air quality in a cost-effective manner, but several design and implementation details need to be improved. The initial endowment of emission permits needs to be tightened for emissions not to increase. Also the endowments need to be firmly defined for different types of polluters immediately (i.e. not subject to manipulation). Further, a two-zone arrangement could be implemented to counteract negative effects of permit trade for central areas, i.e. a ton of emissions in central areas would be treated as equivalent to a higher quantity in outer areas. A clear policy needs to be defined regarding sources that will need compensation only temporarily, for instance, until natural gas from Argentina becomes available. Finally, strict enforcement of the emission compensation system is a precondition for its effective working.

45. The analyzed PM-10 emission controls produce about US$70 million in health benefits, equivalent to US$9 million per $\mu g/m^3$ reduction, or US$18,000 per emitted ton reduced. Thus, at the current level of pollution, controls reducing PM-10 emissions at a cost below US$18,000 per ton should be considered worth-while.

US$18,000 per ton of PM-10 emission can also be seen as a reasonable threshold value for evaluating policies stimulating emission controls, such as general or more directed charges, backed by monitoring efforts (including the calculation of tradeoffs in industry licensing, fuel and energy pricing, licensing of buses for Santiago, equipment standards). If emission taxes can be levied, US$18,000 per ton would be giving appropriate incentives to emission reductions based on conservative estimates. Again, as with the compensation system, a down-town premium could be applied, further improving the effectiveness of the incentives.

46. General energy price increases, as well as increased user charges for wood-fuel and electricity (for the latter, assuming that coal is used extensively at the margin, and that coal-fired power plants are not tightly controlled) can deliver PM-10 emission reductions. Similarly, fuel taxes, differentiated between fuels by emission levels, would create economic incentives for efficient behavior such as shifting from diesel to natural gas or the use of cleaner gasoline.

47. Additional research and analysis is needed on the behavior of entrained dust, and on control strategies for dust. With present knowledge, it would be reasonable to presume that benefits from road dust emission reductions are somewhat lower than the estimated US$18,000 per emitted ton for dust from other sources, due to a lower impact on exposure and a less harmful size and chemical composition. However, road dust could still represent quantitatively important and cost-effective control opportunities, as one can likely find control strategies that are of low cost on an emitted ton basis. Once measures of the health benefits of road paving have been developed, these should be included in the evaluation of transportation sector projects (such as road paving), especially in heavily populated areas.

48. Analysis should be undertaken of other forms of air pollution and the population at risk. The analysis should comprise other pollutants of health importance, e.g. lead, and include indoor and occupational exposure and other factors that are prone to be predisposing factors of respiratory ailments. Ongoing research on particle composition and its mutagenicity/carcinogenicity should be extended.

E. Native Forests Management Options

49. Chile is facing a dilemma how to manage the extensive areas under native forests while still allowing the growth of the dynamic commercial timber sector, largely built on fast-growing exotic species. Forestry is big business in Chile; the sector accounted for about 3.3% of GDP in 1992 and has grown at an annual rate of about 5% per year over the past 15 years. Annual exports of chips, pulp and paper, and wood are now worth more than US$1.2 billion, competing with fresh fruits and fishery products as Chile's most important export after copper. The main base of Chile's vibrant forestry sector are some 1.6 million ha. of commercial plantations. The main environmental issue

of the sector, however, is the management of 7.6 million ha. of remaining potentially productive native forests, and threats to these forests from agriculture, logging, fuelwood extraction, and woodchip production. (The estimated area of native forests is based on a 1981 survey. A new cadastre of Chile's native forests is now being carried out by CONAF and should provide accurate information on the extent and quality of the country's native forests.)

50. Economic forces are the driving factor behind the conversion and/or destruction of areas under native forests. The primary issue is the tradeoff between the economic and ecological benefits of conserving and managing intact native forests as compared to the financial returns from clearcutting and/or conversion of native forests to exotic species plantations, or conversion to non-forestry uses. The main incentive to clearcutting is the high value of standing timber. Recreation and tourism, important industries in many forested areas, offer an opportunity for economic gain while leaving forests relatively intact.

51. Whereas in the past, clearing of native forests for agriculture and livestock was the main cause of forest loss, logging, especially for woodchip production, has become very important recently. Total woodchip exports grew from zero in 1985 to US$ 137 million in 1993, of which 70% now comes from native species. The volume of woodchip exports is expected to continue to grow rapidly.

52. The study area. The study compares the benefits of native forests under present and proposed management regimes with the expected returns from alternative management scenarios, including conversion to other forestry systems (e.g. mixed forests or exotic species plantations) and non-forestry uses. The focus of the study is a transect of the southern part of the province of Valdivia and the northern part of the province of Osorno in the 10th Region, a slice roughly 180 km wide and 80 km deep. About one quarter of the study area, or about 335,000 ha, is forested land. The study transect offers examples of all the major management issues being faced by resource planners in Chile and is at the "frontier" in terms of plantation forestry development.

53. Financial analysis of management options. The financial returns expected from managing native forest lands under various options, including conversion to plantations of exotic species, form the heart of the analysis (Paredes 1994). The focus is on farmers and foresters in their dual roles: as landowners and as producers who desire to maximize land rent -- the net present value (in $/ha) of the continuous stream of net returns from the land. Both exotic species plantations and native forests were analyzed in a NPV framework based on technical and physical factors. Three different discount rates were used: 6%, a social cost of capital; 10%, the cost of capital to large landowners and firms; and 14%, the cost of capital to smaller landowners.

54. The analytical results show that on open or degraded lands, plantation forests of exotic species are always economically more attractive than the planting of native forest species. When land is already under native forests, the value of the standing timber is important and tends to drive the land use decisions. Clearcutting will almost always be the economically preferred option where allowed, followed by the establishment of a plantation of fast-growing exotic species, wherever soil and location make this feasible. If exotic species are not allowed, heavy thinning will be followed by one of several native forest management systems. Experience has been, however, that since the initial "first harvest" financial returns from heavy thinning are so important, many landowners of native forests have taken the benefits from the initial thinning but have often not followed-up with the management plans designed to reestablish the original native species. When the NPVs of exotic species plantations and managed native forests systems are compared at a 6% discount rate, the NPV from exotic plantations averaged over US$5,000 per ha while managed native forests ranged from US$3,000-$4,000 per ha even when the returns from initial thinnings were included. These results illustrate why Chile's native forests are under such pressure.

55. Biodiversity values. One of the primary reasons given for protecting native forests and preventing their conversion or the large scale introduction of exotic species is the need to protect Chile's biodiversity endowment. Although there are considerable protected areas in the 10th Region at present and some 12,000 protected hectares within the study transect, it is also likely that additional areas of native forest need to be set aside to ensure that all threatened flora and fauna are protected.

56. To assess biodiversity needs, a group of experts considered three main questions: 1) identification of important flora and fauna in the transect; 2) identification of presently protected areas; and 3) identification of additional areas in need of protection. The experts identified 78,500 ha in the study area (about 23% of the total area of 334,400 ha) as suitable for protection (Donoso 1993). Although not all of the identified areas are candidates for conversion or other uses (since about 35,000 ha (or 45%) are included in the "critical slopes" category that will prevent most development of these lands), many areas could be developed as managed native forests, or converted to plantation forestry. The opportunity costs of protection (in terms of development options foregone) may be considerable, often as much as US$1,000-$2,000 per ha or more.

57. Tourism and recreation values. The third major dimension of the study focusses on the importance of tourism and recreation as an economic industry in the area (Rios 1993). Tourism is almost entirely centered on natural resources -- especially the lakes and mountains and their forests as the main attractions. Recreation and tourism are substantial and growing industries in the Region. Forests and protected areas are an important part of the overall attraction, especially when combined with the lakes and volcanoes that the Region is famous for, and land values are correspondingly high in recreational areas (as much as US$10,000 or more per ha. for lake-front property).

Watershed impacts of changes in forest uses are potentially important if they result in decreased clarity of stream and lake water.

Recommendations

58. Biodiversity protection goals will not be met by relying on market forces, and additional areas should be protected to preserve all major representative flora and fauna. In the study transect, 23 percent of current forest areas are identified for protection. Where forests to be protected are potentially suitable for conversion, protection can only be accomplished by intervention, usually by the Government, but also in theory by private parties. The advice of "expert groups" is needed to identify those areas that need to be protected, usually through some sort of set-asides as part of the protected area system (SNASPE). Priorities need to be set among those areas identified for protection. When there are several areas that provide the same biodiversity benefits, economic analysis should be used to determine the least cost alternative. The introduction of tradable development options, especially in the case of large private landowners, could help insure that protection needs are met without excessively restricting economic opportunities on native forest lands.

59. In addition to biodiversity, markets also fail to capture the substantial landscape value in certain forested hillsides behind lakes and recreational areas. If these hills are clear felled and converted there may be major costs to recreational users plus the potential for sediment-related damage to the rivers and lakes downstream. This landscape value is important, and will in most cases not be provided by the market. As with biodiversity, intervention will be required, plus some sort of transfer payment or tradeable development permit to compensate those providing the "landscape values".

60. Once biodiversity requirements are met, those remaining forested areas that are not important providers of other external benefits, such as landscape value and soil stabilization, should be considered as economic resources that should go to their highest-valued uses. Depending on the location, the highest-value use may be as protected area for recreational and vacation use, exotic species plantations, managed native forests, unmanaged forest lands, or conversion. Study findings indicate that the difference in present value between managed native forests and plantation alternatives may be as much as 100 percent or US$2,000-2,500 per ha. at a 10 percent discount rate.

61. The rapid growth, and economic importance, of the tourism/recreation business in the 10th Region requires increased government and private sector investment in infrastructure and facilities for visitors. CONAF will need to expand and improve its visitor handling facilities to accommodate increased use of protected areas while avoiding unnecessary damage to fragile ecosystems. Private concessionaires can play an important role in providing visitor services within parks. At the same time, the growth of privately funded "ecological developments" (including both resort areas and productive facilities

such as aquaculture), that claim to be done in an environmentally-friendly manner, also require supervision to minimize negative environmental impacts from domestic sewage, waste water, and other potential problems.

62. Currently, a large share of the depletion of native forest occurs in violation of existing regulations. Also, there is low compliance with management plans requiring reforestation. Chile's remaining native forests are a potentially valuable resource, and their use should be determined by conscious policy-making. Priority should be given to the definition of an overall native forest policy. Weighing costs and benefits, a political decision needs to be made with respect to how much and which native forests to conserve. This decision should then be strictly enforced. The current uncertainty about future regulation is detrimental to forest management and should be resolved quickly. The ongoing compilation of a national forestry inventory will provide a better information base for informed policy making and should be pursued with high priority.

63. The government should ensure satisfactory budgeting of sector institutions, which would allow them to carry out their mandate and effectively enforce sector policies, including the monitoring of reforestation. The enforcement of existing regulation should be improved, even before the compilation of the national forest inventory is completed. Particular attention should be paid to protect the rights of indigenous groups affected by illegal logging activities. Performance bonds deposited at the time of logging and released once agreed management plans are executed could potentially improve performance and reduce supervision costs. The release of non-proprietary information in forest management plans to the public could help improve compliance with regulations through public surveillance.

64. There is insufficient experience with the sustainable management of native forests. Research is needed to analyze the potential of native forest management techniques that retain the ecological value of the forest and still provide adequate financial returns. The development of cost-effective ways for financing native forest management, which provides external benefits (watershed benefits, landscape values), through an extension of subsidies to certain types of native forest management should be analyzed. Research is also needed to analyze the ecological effects of the large scale expansion of eucalyptus plantations.

I. THE NATURE OF ENVIRONMENTAL PROBLEMS IN CHILE[1]

A. Background

1.1 Chile has experienced a period of strong economic growth and a high degree of economic stability that has been attributed to consistent, market-based economic policies. However, as growth has proceeded at a rapid pace, the health and productivity costs of environmental degradation have become apparent. Concerns have emerged about the environmental costs of the extraction and use of natural resources as well as pollution. The main environmental issues that Chile is facing are: (a) urban pollution of air and water; (b) industrial pollution by localized industries, in particular mining; and (c) the intensive use of natural resources, including native forests, fisheries, and soils. The concerns about environmental degradation are highlighted by the extraordinary economic importance of those sectors that are associated with the use of renewable resources (agriculture, forestry, and fisheries products), and industrial pollution (mining).

1.2 Urban Pollution. Part of the price of rapid and unmanaged economic growth and continued urbanization is the pollution of air and water. The degradation of the urban environment is very visible, and the costs of health damage and productivity losses due to air and water pollution in Santiago are large. The highest profile issue remains the serious level of air pollution in Santiago from fixed and mobile sources. Water pollution in the central region is caused by the discharge of untreated sewage and industrial effluent.

1.3 Localized Industrial Pollution. Industrial pollution arises primarily from the mining and smelter operations in the north and the center of the country. Mining activities are site specific, but the environmental impacts are large. They include contamination of air, water, and soil with particulates, sulfur, arsenic, and other toxic substances. Other important sources of industrial pollution are fossil fuel users, as well as the pulp and paper industry in the south.

1.4 Natural Resource Management. The most pressing natural resource management issues in Chile are those associated with forestry and fishery. These industries have rapidly expanded in response to a favorable macroeconomic policy framework and strong external demand. While growth of the forestry sector is primarily based on the expansion of plantation forests on previously degraded lands, the most controversial environmental problem of the sector is the depletion of native forests as

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1. This chapter was written by Joachim von Amsberg, drawing on background material provided by Ricardo Katz. The references to previous studies, on which this chapter is based, are given at the end of this report.

sources of fuelwood and raw material for wood chip production. The expansion of the fisheries sector has led to a situation of full exploitation of the commercially important species that, due to natural stock fluctuations, implies significant risks for the sustainable management of the resource stocks.

1.5 Prior to 1990, there were only fragmented environmental regulations and almost no enforcement. Since then, the government has made environmental protection a priority. Very significant progress has been made over the last four years in putting environmental issues on the political agenda and establishing an institutional and regulatory framework for addressing environmental issues. The government has introduced environmental considerations into most areas of policy making, established a central coordinating agency for environmental policy and created the legal framework for environmental management. However, the remaining challenges are formidable. Key issues to be addressed include the continuing air pollution problems in Santiago, decisions about investment proposals in the magnitude of US$1 billion for sewage treatment and the ongoing conflict about forest conservation.

1.6 The purpose of this report is threefold. First, it provides an overview of environmental problems in Chile and outlines steps toward an environmental strategy. Second, the three chapters on air and water pollution in the Santiago Metropolitan Region, as well as native forest management in a study area (in Region X) provide an in-depth economic analysis of three of the most serious environmental problems in Chile. Third, the report demonstrate the use of methodologies and the application of economic analysis tools to complex environmental issues. Even though the report focusses on three discrete environmental problems, it is suggested that the same analysis tools could also be applied to other environmental problems.

1.7 This report demonstrates that Chile's growth has had significant environmental implications. The exploitation of natural resources has led to investments, for example in forest plantations, but also to the depletion of resource stocks, for example the native forests. This report attempts to apply systematic economic analysis to environmental problems for determining efficient environmental policies and selecting policy and investment options that improve environmental quality. These efficient environmental policies can reconcile the objectives of economic development and environmental protection. Efficient environmental policies should internalize environmental costs. These costs will then work their way through the economy, and prices throughout the economy will include environmental costs. As a result, efficient environmental policies would increase the overall welfare in the economy.

1.8 This report does not attempt to address comprehensively all environmental problems of Chile. It focusses on three among the most important environmental management problems of the country. Other important environmental problems, such as mining sector pollution, are not analyzed in detail. Related issues, such as indoor air pollution and workplace safety, are not included in the report. Natural resource management issues, other than biodiversity conservation in native forests, are not addressed. The question of how to allocate Chile's natural resources, the mines, forests, fisheries, water, and soil, over time and between competing uses is of crucial importance to the Chilean economy but outside the scope of this report. In order to provide on overview, this introductory chapter presents a brief summary of the important issues that are not analyzed in detail and includes some suggestions for their further analysis and the development of management strategies.

1.9 World Bank Involvement. The World Bank Group is involved in several initiatives for environmental management in Chile. The Bank has supported water supply and sewerage investments in Santiago (Second Santiago Water Supply Project, Loan 2651-CH) and Valparaiso (Second Valparaiso Water and Sewerage Project, Loan 3331-CH). In 1992, the Bank approved the Environmental Institutions Development Project (Loan 3529-CH), which supports the development of an institutional and regulatory framework for environmental management in Chile. The objectives and components of this project are summarized in Annex 2. The Bank is currently preparing a project for integrated water management in the Bío-Bío river basin. Simultaneously, a research study is under preparation that examines the functioning of water markets in Chile. The International Finance Corporation (IFC) is preparing plans for an investment in a hydropower plant on the Bío-Bío river (Empresa Electrica Pangue S.A.). Finally, the Bank also administers the financing of a US$2.1 million grant under the provisions of the Montreal Protocol to assist Chile in eliminating the use of ozone depleting substances.

1.10 Other Donor Involvement. Several bilateral and multilateral agencies and donors are supporting or planning to support environmental projects and natural resource conservation measures in Chile. The German Technical Cooperation Agency (GTZ) supports a program that includes the development of clean technologies, solid waste management, energy efficiency, soil conservation and management of hydraulic resources. The Inter-American Development Bank (IDB) is providing assistance in the area of Environmental Assessment and the development of institutional capacity in the forestry sector. USAID is providing assistance, among others, in the areas of biodiversity, development of environmental quality indicators, and solid waste management. Finally, UNDP coordinates technical assistance under the Global Environment Facility (GEF).

B. Environmental Regulations and Institutions

1.11 The economic policy under the military government (1973-1990) emphasized the development of a free-market economy based on non-interventionist principles and a strong export-orientation. Environmental protection was viewed as detrimental to economic growth and neglected. The population effected by environmental problems was largely excluded from political decision-making. There was neither a coherent body of environmental regulations nor a central environmental authority in Chile. Environmental rules and regulations were fragmented and without effective enforcement. There was no national legislation requiring the assessment of environmental impacts of investment projects, and new projects were approved and modified on a case-by-case basis. Basic environmental data was either lacking or collected sector by sector and not compiled in a manner useful for environmental management.

1.12 The transition to a popularly elected democratic government in 1990 represented an important political milestone and has resulted in an increasingly open debate about the future of the country. Both the people and the government have become aware that the environmental cost of past growth is being borne by the population at large and the country's natural resources base. The Aylwin government has made protection of the environment and responsible management of Chile's rich natural resources an important part of its program. In his speech to a joint session of Congress on May 21, 1992, President Aylwin outlined the government's strategy for improved environmental management and cited environmental management as a central element of the development strategy for the country. The new government of President Frei, which took office in March 1994, is expected to continue this emphasis on sound environmental management.

1.13 There is a strong commitment on the part of the government to environmental protection, and the environmental sector has been undergoing a process of rapid change and maturation. The government has taken many important steps to address the issues and to improve the previously fragmented regulatory and institutional framework for environmental policy. At this stage, however, the institutional and regulatory framework still requires substantial strengthening.

1.14 The government's strategy is a practical one that is based on the "polluter pays" principle and combines the use of both economic incentives and direct regulations to promote efficient and sustainable development that explicitly takes environmental factors into consideration. Priority areas have been attacked first. The need to develop the capability for improved environmental management is stressed, as is the importance of active community and business participation in the process of policy design and implementation. Prevention of environmental problems is recognized as more cost-effective than ex-post cures. Institutional strengthening is a key component of the government's strategy. With its emphasis on market-based policies, the government, in theory, favors environmental policies based on market-based instruments. In practice, however, command-and-control regulation is still the most common approach.

The Regulatory Framework

1.15 The Chilean constitution in Article 19.8 alludes to the right to live in an environment free of contamination and assigns to the government the responsibility for enforcing this right and guarding the preservation of nature. Beyond this constitutional right, there was no coherent legislative framework governing environmental management. Instead, there was a proliferation of sectoral ad-hoc regulations affecting the environment. Since action was generally only taken to address particularly severe localized problems, regulations were incomplete, overlapping, and in part contradictory. As a result, there are more than 2,000 specific environmental regulations contained in about 700 laws and decrees. There is often uncertainty about the validity of and institutional responsibility for regulations, and many regulations are not effectively enforced.

1.16 At the sectoral level, regulations that directly affect environmental management include legislation pertaining to subsidies for commercial afforestation (Law 701/1979), agricultural protection (Law 3557/1980), automotive vehicle emissions (Decree 211/1991), fisheries (Law 18892/1991); the regulation of SO_2, arsenic and particulate emissions (Decree 185/1991), and particulate emissions from fixed sources in the Santiago Region (Decree 4/1992).

1.17 In Chile, public sector investment projects undergo financial and economic review within the Ministry of Planning at the pre-feasibility stage, but until now were not generally required to undergo a formal assessment of environmental impacts. Most public and private sector investments require not only a construction permit from the local municipality but also the approval from several sector ministries, such as mining, public works, or agriculture. Through these approval processes, sector ministries have already applied some measure of environmental control, although in an ad-hoc manner and through special decrees. The sectoral ministries are currently upgrading their so far limited environmental management capacity. Also, many private sector companies are establishing departments responsible for environmental affairs.

1.18 In an attempt to bring a systematic approach to environmental regulations, the parliament passed in early 1994 the Basic Law about the Environment (Law 19.300), which went into effect on March 1, 1994. The Basic Law establishes a framework for environmental management in Chile and specifies the details of the constitutional guarantee to an environment free of contamination. It is expected that this law will help clarify legal conflicts that have arisen in the past between this right and individual property rights that are a central pillar of the constitution and the Chilean economy. The Basic Law determines the instruments of environmental management, establishes the principle of liability for environmental damage, and establishes the institutional framework for environmental management.

1.19 For private and public sector projects, the Basic Law creates a unified system of environmental impact assessment (EIA). (EIA is a procedure by which environmental hazards and costs associated with a project are systematically identified, analyzed and evaluated, and measures for the prevention or mitigation of environmental damages are formulated.) The EIA process applies to essentially all projects of industrial scale. Projects that meet particular criteria indicating potential environmental problems require a comprehensive environmental impact study. Other projects require a simplified environmental impact declaration. Applicants have to submit the environmental impact study/declaration for evaluation to the Regional Environment Commission (COREMA). COREMA coordinates the approval process between the various sector ministries and services. COREMA accepts or rejects the application within a determined time. The permit issued by COREMA subsumes all environmental permits previously required from different government agencies, and, hence, potentially simplifies the application procedures significantly. The detailed regulation of the EIA process is expected to be completed by the end of 1994.

1.20 Other instruments of the Basic Law include the promotion of environmental education and research, procedures for setting emission standards as well as standards for ambient quality, the preservation of nature and conservation of the natural heritage. The Basic Law creates procedures for implementing management plans for natural resources, decontamination plans for areas where ambient quality exceeds standards (saturated areas) and prevention plans for areas where ambient quality approaches standards (latent areas). The instruments to be used under these plans include emission standards, tradable emission permits, and environmental taxes. The law requires community participation in the evaluation in the EIA process and in the generation of the above-mentioned plans and standards.

1.21 The Basic Law creates a useful framework for improved environmental management. However, the passing of the law alone will not immediately unify the full range of fragmented environmental regulations. Before all aspects of the law can become operational, it will be necessary to supplement the Basic Law with specific environmental regulations. Sectoral laws and regulations will need to be issued that deal with the detailed aspects of the EIA process as well as soil, water, air and forest protection in a unified approach consistent with the framework provided by the Basic Law.

The Institutional Framework

1.22 Formal environmental institutions are relatively new in Chile. The lack of integrated institutional responsibility for setting, monitoring, and enforcing environmental policies has been a serious problem. Responsibility for environmental issues that is assigned along sectoral lines hinders integrated environmental management. As a result, sector authorities followed their sectoral interests and have issued regulations that are in many cases contradictory.

1.23 Based on the view that the environmental is not a separate sector but a concern that is of importance to all economic sectors, the government decided to address environmental issues not through a large centralized agency or a separate ministry but through a coordinating body. In 1990, the government created the National Commission for the Environment (CONAMA, Decree 240/June 5, 1990, replaced by Decree

544/October 9, 1991) as a small environmental agency to coordinate and implement national environmental policies, strategies, and action plans. CONAMA's work is supplemented by units in each ministry responsible for addressing environmental issues according to the policies set forth by CONAMA.

1.24 Passed in early 1994, the new Basic Law has provided CONAMA with a permanent organizational framework. CONAMA is now reporting directly to the Minister of the President's Office (Ministerio Secretaría General). Political guidance is given to CONAMA by the Council of Ministers (Consejo Directivo), which includes the ministers of economy, public works, agriculture, national assets, health, mining, housing, transport, and planning. CONAMA itself is headed by an Executive Director appointed by the President of Chile and supported by an advisory council. Similarly, the Basic Law establishes Regional Environment Commissions (COREMAs). The law assigns CONAMA 62 regular staff positions which already includes one staff position for the regional director of each of the 13 COREMAs. These regular staff positions are supplemented by consultants.

1.25 The Basic Law assigns CONAMA the task of coordinating the setting of standards and other environmental policies. This year, CONAMA will prepare key regulations on procedures for EIA and standard setting. In the medium-term, CONAMA plans to prepare legislation regarding water, air, and soil pollution as well as biodiversity protection and environmental liability. The Basic Law assigns to the COREMAs, or to CONAMA if more than one region is affected, the task of evaluating EIAs as well as developing management plans and implementing pollution control measures through decontamination and prevention plans.

1.26 The passage of the law creates an important opportunity to improve environmental management in Chile. However, CONAMA and the COREMAs do not yet have the capacity to adequately fulfil the responsibilities assigned to them by the law. Bottlenecks are expected specifically for the administration of the EIA process. Annually, about 600 environmental impact studies will have to be evaluated starting in 1995. For this task, the law provides for no more than one staff position in each region. Since evaluation capacity is very limited and the law dictates a time limit of 120 days to reject an EIA, there are risks that the new procedures will allow environmentally harmful projects to proceed that previously would have been stopped during the sectoral reviews, which will be unified under the new EIA process.

1.27 The strategy in the development of CONAMA remains the strengthening of key institutional functions and appropriate units in the line ministries and not the replacement of their functions. CONAMA is playing a catalytic role in helping to define the broad policy framework and provide selected service functions (such as environmental data collection, analysis and EIA training) to the rest of the public sector. With the assistance of the Banks' Environmental Institutions Development Project, and sustained political support from the government, CONAMA is now developing into an effective organization for coordinating the national effort on environmental policies and issues.

1.28 In line with the overall political constitution of the country, environmental regulation and management are highly centralized. Regional administrations report to the central government. With the main environmental functions assigned to sector ministries and their regional services as well as to CONAMA and the COREMAs, responsibility for most environmental matters ultimately rests with the central government. In contrast, municipal administrations are elected directly but have only indirect environmental responsibility through the granting of building permits.

1.29 In 1990, the government created a Special Commission for the Decontamination of the Metropolitan Region (CEDRM) under the Ministry of the Interior to address the high levels of pollution in Santiago (Decree 349/1990). CEDRM has made progress in the area of air pollution; however, attempts by CEDRM to coordinate the different actors responsible for water quality management in Santiago have hit numerous roadblocks. It is planned to integrate CEDRM with the framework created by the Basic Law within the next two years. CEDRM would then become the COREMA for the Metropolitan Region of Santiago.

1.30 Non-Governmental Organizations (NGOs). NGOs have played an important role in increasing the public awareness of environmental problems in Chile. CIPMA, the Environmental Research and Planing Center, lobbied for improvements in environmental management already under the military government. CODEFF, the main environmental advocacy NGO, focusses on the conservation of natural resources and preservation. The business sector participates in discussions on environmental matters through the Center for Public Studies (CEP). Other NGOs are also active in the areas of creating public awareness of environmental problems, political lobbying, education, and research. With the principle of public participation in the EIA process established in the Basic Law, it can be expected that NGOs will play an increasing and important role in the process of environmental decision making

C. Water Quality

1.31 Chile's surface water resources consist of a series of river systems, all of which originate in the Andes and drain to the west into the Pacific Ocean. Water scarcity is becoming a critical constraint in the northern regions, aggravated by the mining sector's high use of water. Water pollution is most serious in the north (fish and mining industries), the Metropolitan Region of Santiago, and the central seaboard (sewage and industrial pollution), and the bay of Talcahuano (fisheries, petroleum, and pulp industries). In the south, periodic flooding poses an additional problem. Water pollution is a major issue in most areas of the country due to lack of adequate treatment for domestic and industrial waste. Polluted rivers also contaminate coastal areas and, thus, affect local fishery operations; they also foul areas used for tourism and recreation. Finally, groundwater pollution is an important emerging problem.

1.32 Water is a natural resource that provides a wide range of services, including supply for irrigation, industry and households, support of fish populations and recreational uses, generation of electricity, as well as a medium for flushing away and treating domestic and industrial wastes. Some of these uses are consumptive (i.e., irrigation), others are non-consumptive (i.e., fisheries). Some uses are non-consumptive but restrict or even exclude other uses (i.e., effluent disposal). For consumptive uses, water is a private good for which property rights can be allocated. In other uses it is a public good (i.e., recreation) and typical externality problems arise. Water quantity and quality are fundamentally linked and cannot be analyzed in isolation. The presence of contamination, for example, limits the availability of water for consumptive uses in two ways. First, water downstream of the source of the effluent may no longer be suitable for the intended use without additional costs to the user. Second, users upstream of the source of the effluent are unable to exploit water flows fully because a reduced volume in water bodies would increase the concentration of contaminants for downstream users.

1.33 Sewage Contamination. An international comparison of river pollution (Table 1.1) underlines that microbiological contamination is the main water quality issue. Even though sanitation services in Chile are well developed (82 percent of households in the whole country, and 94 percent of urban households have access to potable water; similarly 76 percent of households have adequate sewerage), the disposal of collected waste water is inadequate. Subsequently, biological pollution of waters is common in Chile, particularly close to cities.

1.34 The concentration of fecal coliform exceeds the irrigation water standard of 1,000 fecal coliforms per 100 ml in almost all rivers, reaching levels above 100,000 per 100 ml in the worst cases. The rivers running through Santiago and the coastal areas of Region V are particularly affected by the dumping of untreated sewage into open water courses with serious effects on the population's health. With the exception of a small pilot plant in Santiago that treats about 4 percent of the city's waste water, there are no sewage treatment plants. So far, no decision has been taken on waste water treatment beyond this pilot plant. The health problems associated with polluted irrigation water and the policy options for water quality improvements in the Santiago Region are analyzed in detail in chapter II.

1.35 Along the Valparaiso coast where another 10 percent of the population live (a share greatly expanded during the summertime), untreated sewage is discharged into the ocean. It contaminates local beaches to levels that have required their closure. The rivers bearing sewage from Santiago and other urban centers of the Region as well as local industrial discharges add to the localized contamination of the sea. The ongoing

Table 1.1: Water Contamination in International Comparison

City	BOD_5 (mg/l)	Suspended Solids (mg/l)	Fecal Coliform (per 100ml)
Garang, Indonesia	2.30	245.00	82,500
Maipo, Chile	**15.00**	**8.00**	**53,447**
Rapel, Chile	**1.29**	**0.24**	**44,391**
Mataquito, Chile	**0.50**	**0.15**	**33,086**
Maule, Chile	**0.25**	**0.31**	**12,374**
Paraiba, Aparecida, Brazil			6,075
Danube, Hungary			3,750
Rhine, Netherlands			2,050
Yellow, Huanghe, China	1.18	6,822.00	2.950
Mississippi, Vicksburg, USA			1,473
Chilean Water Quality Standard for Irrigation			1,000
US Ambient Water Quality Standards	4.00		500
WHO Drinking Water Guidelines		1000.00	0-10

List includes rivers in Chile's central regions with a flow of more than 250 million m^3/month and selected rivers in other countries; latest year available.
Source: World Bank (1992), UNEP (1993) for international data; SSS for Chilean rivers.

Second Valparaiso Water Supply and Sewerage Project will improve the sewerage system in the Valparaiso area using an environmentally acceptable marine sewage disposal system.

1.36 Water pollution from agricultural runoffs (agrochemical pollution) has not been analyzed in detail but needs to be studied. The fact that a significant share of agriculture output is exported has a positive effect, since export foods must meet the relatively stringent quality requirements of the importing country. As a result, application rates of chemical fertilizers and pesticides are relatively low, leading to lower levels of agrochemical residues in soil and water runoffs. It is not clear whether this effect spills over to the production of non-food products or production for the domestic market. There are indications of a double standard, with higher quantities of agrochemicals applied on agricultural products for the domestic market.

1.37 Information on the level of industrial pollution of waterways is limited. The Superintendencia de Servicios Sanitarios (SSS) has recently compiled a national inventory of industrial effluent. This inventory is based on company responses to a questionnaire issued by the SSS and contains only limited information on the composition of industrial effluent. In a pilot program for the Maipo, Bío-Bío, and Aconcagua river, a more detailed analysis of industrial effluent of selected industries is under preparation. As a matter of example, toxic substances and heavy metals have been detected in surface waters near mining sites and industrial zones. Metal levels above irrigation water standards were detected for copper, iron, and aluminum (Mapocho river), chromium (Zanjon de la Aguada), and manganese (Mapocho, Maipo, and Zanjon).

1.38 Institutions. So far, no unified water management policy has emerged and responsibility for water resource management is fragmented and overlapping. For example, the Ministry of Health, Servicio de Agrícola y Ganadero (SAG), Dirección Nacional de Riego (DNR), and the Ministry of Public Works through its Dirección General de Aguas (DGA) all have some responsibility for enforcing the Chilean Standard 1,333 for irrigation water quality and a coordinated approach has not been achieved. The revised water code of 1981 charged the municipalities with direct responsibility for implementing laws on water quality, and gave the DGA wide powers to apply the law and coordinate the various agencies whose mandates touched on water quality. DGA, however, does not have sufficient resources to carry out this task. Simple agreements are necessary on questions like where do standards apply, and where and how to monitor.

1.39 Regarding industrial wastewaters, the first laws were promulgated in 1916 but remained without corresponding regulation until the Decreto Supremo No. 351 issued in 1993. Only with the creation of the Superintendencia de Servicios Sanitarios (SSS) in 1990 has serious attention been given to the problem of industrial discharges into municipal sewer systems. The SSS has made progress on an industrial discharge inventory for the SMR and the formulation of pretreatment and discharge standards. It is still not clear, however, as to what policy instruments are needed and how the eventual standards will be applied. Industrial discharges are likely to limit wastewater reuse and cause other water pollution problems in the future unless effective control policies are promulgated by SSS and implemented by the water and sewerage utilities and the industrial sector.

1.40 Standards. Ambient water quality standards have been set by the Ministry of Health for drinking water and the Ministry of Agriculture for irrigation water. There are also water quality standards for recreational use and aquatic life. Generally, these standards are in line with WHO recommended guidelines. There is no systematic enforcement of these standards. The standards for some metals and arsenic are exceeded by natural background concentration in most rivers. In many cases, it has not been determined which ambient standard is applicable to a specific body of water. Provisional regulation by the SSS determines effluent standards that are independent of the nature of the receiving watercourse. These effluent standards are also used as a guideline by the Navy Department charged with supervising discharges into the ocean and large inland waterbodies.

1.41 The Water Code of 1981. Chile is unique with its market based approach to water resource allocation. The water law of 1981 (Código de Aguas) formalizes the principle of private ownership of water rights and reverses the predominant role of the government in water management in the previous law of 1968. Subsequently, water users have been assigned different types of transferable rights to consumptive and non-consumptive water usage, and markets for these rights have been created. In the agriculture sector, the allocation of water usage rights has led to benefits due to the increased security of water supply. However, due to high transaction costs and rigidities in the irrigation infrastructure, transactions in water usage rights are still infrequent.

1.42 So far, the market based system of water rights has not succeeded in solving intersectoral water use conflicts. Even though the law has created rights for non-consumptive water usage, the water user associations that administer the water basin systems generally do not include non-agricultural water users. There is no clear legal framework to resolve conflicts between different sectors and different types of water usage rights. Also, the current system ignores water quality aspects and collides, in some instances, with measures for water quality improvements. For example, one of the obstacles to assigning standards to specific waterways is the legal position of the holders of water usage rights. The owner's position puts legal limitations on the ability of the regulators to impose ambient water quality standards an specific bodies of water. The World Bank is supporting the development of a pilot project in the Bío-Bío river basin for river basin based integrated water management of all water uses. The projects supports the intention of legislative changes currently underway that would grant the authority for sector-integrated water resource management to self-financing river basin corporations.

D. Air Quality

1.43 Air Pollution in Santiago is the most obvious environmental problem of the country. Santiago's serious air pollution problems are aggravated by the city's location in an enclosed valley with limited wind and little rain as well as thermal inversion throughout most of the year, which limits the dispersion of emissions from traffic and industry. Table 1.2 puts Santiago's air quality in an international perspective. Air pollution is also a significant problem in Concepción-Talcahuano resulting from the steal, petroleum, fishmeal, as well as pulp and paper industries. So far, there is no consistent air quality monitoring in Concepción, but it is expected that this city will follow Santiago in some of the policy measures described below. High levels of ground-level ozone have recently been observed in Valparaiso-Viña del Mar.

1.44 The main conventional atmospheric pollutants in Santiago are total suspended particles (TSP), particle matter smaller than 10 micron (PM-10), carbon monoxide (CO), ground-level ozone (O_3), nitrogen oxides (NOx) and sulfur oxides (SOx). Air pollution in Santiago results from a combination of transport (diesel fuel) and industrial sources. SO_2 originates primarily from industrial processes. NOx and CO originate primarily from vehicles. TSP pollution is caused in large part by street dust

Table 1.2: City Comparison of Air Pollution

City	Total Suspended Particles	Sulphur Dioxide
Calcutta	393	54
Beijing	370	115
Tehran	261	165
Mexico City	100-500	80-200
Bangkok	220	34
Santiago	**210**	**38**
Manila	120-250	20-50
Athens	178	34
Bombay	140	23
Sao Paolo	50-85	35-62
Los Angeles	46-115	0-10
New York	61	60
Tokyo	51	20
WHO Recommendations	60-90	40-60

Because of differences in location and measurement, city comparisons are only indicative.
Commercial City Center, $\mu g/m^3$ annual averages, latest year available.
Source: WHO/UNEP (1992), World Bank (1992), other World Bank reports.

blown from unpaved roads, open lands and eroded hillsides surrounding the city. Diesel buses and industrial sources also contribute significantly to PM-10 emissions. Conventional urban air pollutants are considered the most important problem. In addition, there is atmospheric pollution with toxic substances, such as lead and hydrocarbons. Preliminary analysis indicates that lead contamination poses no significant problem, however, additional study of these problems is required. Atmospheric emissions that give rise to global rather than local problems, such as carbon dioxide and chlorofluorocarbons (CFCs) are discussed in separate sections.

1.45 The biggest threat to health comes from fine particulate matter (PM-10) that is inhaled deeply and can damage the lungs. Studies have shown significant effects of the air pollution levels found in Santiago on human health, including premature death and respiratory deceases such as chronic bronchitis, pneumonia, and asthma. Other health effects include coughing, snoring and night awakening. The costs of air pollution include the costs of cleaning, reduced vegetation and agricultural productivity, as well as vision impairment resulting in lost amenity value and lost revenue from tourism. An additional cost category is productivity losses incurred due to emergency measures imposed during periods of intense air pollution.

Table 1.3: Chilean and WHO Ambient Air Quality Standards

$\mu g/m^3$	Chilean Standard (Primary)*	WHO Recommendation
CO (1 hr)	40,000	30,000
CO (8 hrs)	10,000	10,000
SO_2 (24 hrs)	365**	100-150
SO_2 (1 yr)	80**	40-60
O_3 (1 hr)	160	150-200
NO_2 (24 hrs)	100	150
TSP (24 hrs)	260	150-230
TSP (1 yr)	75	60-90
PM-10 (24 hrs)	150	100-150

Chilean Standards: Resolution 1.215 and Decree 185.
* Primary standards apply to the full geographic area of the country and define an emergency situation.
** Secondary SO_2 standards of $60\mu g/m^3$ (1 yr) and $260\mu g/m^3$ (24 hrs) apply in the southern half of Chile.

1.46 National air quality standards have been established by the Ministry of Health for each of the important pollutants. These standards were set at levels similar to those in other countries and those recommended by the WHO (see Table 1.3). Air quality standards are goals any policy should aim at reaching. However, they are not legally binding. It is estimated that the population of Santiago is routinely exposed to concentration levels that violate the air quality standards for TSP, PM-10, and CO in winter (April to October) and for O_3 in summer (November to March). NO_x and SO_2 concentrations do not routinely violate standards at current monitoring stations but are likely to violate standards closer to polluting sources.

1.47 A special commission for the decontamination of the Metropolitan Region (CEDRM) was established in 1990 to confront the issue of pollution in Santiago. Due to resource constraints, actions were taken primarily for the reduction of PM-10 and CO but not yet for O_3 and other pollutants. Several initiatives have been launched including the establishment of emission standards for different fixed and mobile sources. It appears that the measures taken over the last three years are insufficient to lead to a significant improvement in air quality. However, at least for particulates, the decline in air quality has been arrested despite a continuing increase in population and industrial activity (see Figure 1.1). Some of the measures taken are expected to produce air quality improvements over time.

1.48 Within its short-term program, CEDRM established *pre-emergency* and *emergency* measures when air pollution measurements exceeded certain critical levels. The declaration of emergency measures is based on pollution indices for PM-10, CO, SO_2, NO_2, and O_3. However, real time measurements of PM-10 are available only in the downtown area, and possible problems in other areas could go unnoticed. The emergency

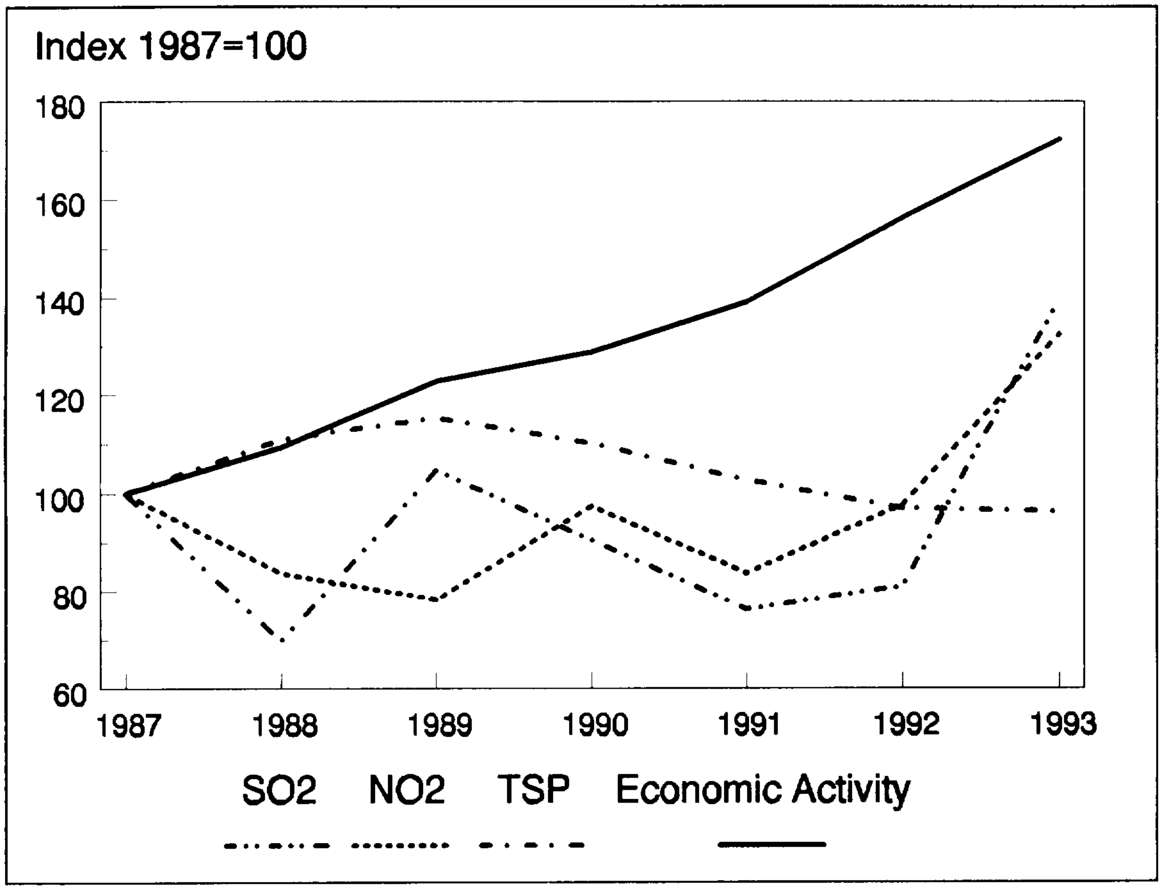

Figure 1.1 Indices of Ambient Air Quality and Economic Activity in Santiago

measures include the closing of schools, restricting the operation of polluting industries, and limiting the operation of vehicles. Table 1.4 shows the days of pre-emergency and emergency measures during the last years, generally occurring between May and August.

Table 1.4: Emergency Measures in Santiago

Year	Days of Pre-emergency	Days of Emergency
1990	11	2
1991	9	2
1992	14	2
1993	8	0

Source: CEDRM

1.49 Transport. Of the 6.5 million daily movement in the Santiago area, 30 percent are on foot, 50 percent by public transport, and 20 percent by car. Consistent with low motorization (90 vehicles per 1,000 inhabitants), mass transit is the dominating mode. Of all motorized trips, 53 percent are by bus, 28 percent by car, 12 percent by Metro and 7 percent by taxi (BKH Consulting, 1992). Until recently, there were no effective controls on vehicle emissions. Moreover, there were no restrictions on private operators of urban bus services, which have proliferated after the deregulation of bus transport in the early 1970s. As a result, a large number of used diesel buses and used replacement diesel engines were imported at low cost and operated nearly empty during most of the day. Without emission restrictions, there was no incentive for engine maintenance that could have reduced diesel bus emissions by a factor of ten according to some estimates.

1.50 The new measures taken to control air pollution include the introduction of vehicle emission standards that, in practice, will make the use of three-way catalytic converters obligatory for new light-duty vehicles (Decree 211/1991). Testing of individual vehicle exhaust emission factors is now regularly performed in Santiago. On any given day during the critical season, the operation of 20 percent of the vehicle fleet is restricted. Moreover, in early 1991, Santiago banned 2,600 pre-1972 buses, constituting one-fifth of the bus fleet.

1.51 A revised system for bus operators has been implemented that introduces tighter emission standards for new buses and limits the types of buses operating on downtown routes. The totally unregulated system of bus operation has been replaced with a new approach in which the right to operate on Santiago's congested streets are auctioned on the basis of bids which contain service characteristics including price and type of bus. These reforms have helped speed up transit times, reduce congestion and pollution, increase occupancy rates, and bring down fares. In addition, the new regime has prompted private investment in two trolley lines in the downtown area. Additional steps are being taken to expand and improve the public transit system, including the expansion of the subway system.

1.52 Industry. Industrial pollution was largely uncontrolled until 1990 and there is no complete inventory for sources of industrial air pollution except for PM-10 emissions in the SMR. Centers of industrial air pollution outside the Metropolitan Region include the copper smelters and refineries in the north and the center, as well as petroleum-based industries in Concepción and in the Valparaiso area. Fish processing industries in the north and south also pollute the air with foul smelling contaminants. Analysis of industrial pollution problems has been hampered by lack of information as well as conflicting institutional responsibilities. Except for the Santiago Region, where an important set of basic studies was carried out, information on the sources and impact of industrial pollution is poor. The World Bank's Environmental Institutions Development Project would help improve information on the nature and extent of pollution problems and develop industrial pollution policy papers and related action plans.

1.53 Industrial emission sources of PM-10 in the Santiago Region have been addressed by a Decree (No. 04/1992) which provides the policy framework for a transferable pollution rights approach. This decree combines an emission standard with a compensation system to be phased in until 1997. The initial distribution of emission rights is based on gas flows as reported in March 1992. Starting in 1994, any new emission source requires compensation from an existing source. However, no trades have taken place as of May 1994.

1.54 The PM-10 compensation system in Santiago is an innovation at an early stage of implementation. This system of tradable pollution permits has the potential to achieve a desirable level of pollution reduction at the least possible cost. However, attention needs to be paid to the implementation details of this system. In particular, a situation should be avoided whereby emission permits are issued in excess of current emission levels or trade in permits leads to a migration of emission sources into areas with greater air pollution problems, such as the downtown area. For a permit trading system to work, a stable institutional framework is required. As long as enforcement is weak and there is still uncertainty about the exact definition of the initial pollution inventory on which trades are based, or the measurements of emissions from different processes, the system is unlikely to work effectively.

1.55 Additional uncertainty for the PM-10 compensation system is created by the expectation that natural gas from Argentina will be available in Santiago shortly after the last step in the implementation of the emission compensation system in 1997. The administration needs to take a firm position now on how it will handle pollution sources that would require compensation only for a short period of time between 1997 and the introduction of natural gas. In the long-run, the possibility of trades between different groups of emission sources (fixed and mobile sources) would be desirable, taking into account the differences in emission effects on ambient air quality.

1.56 Other measures taken for improving air quality in Santiago include a ban on the use of wood-burning fireplaces during the entire year. The street paving component of the World Bank supported Urban Transportation Project complements the other efforts for reducing particulate levels in the air by reducing street dust. A gas pipeline from Argentina to Chile is being planned and the likely first use of gas would be as a substitute for diesel in the industrial sector of Santiago, thus reducing the air pollution problems. As an additional measure for dust reduction, the feasibility of reforesting eroded hillsides surrounding the city should be evaluated.

E. Mining Sector Pollution

1.57 The mining sector plays a key role in the Chilean economy, constituting 55.9 percent of foreign direct investments, 47.3 percent of exports and 8.2 percent of

GDP. The principal mining activity is the extraction of copper. With an extraction of 2.0 million tons per year (1993), Chile is the world's largest copper producer. Annual extraction is expected to increase to 3.7 million tons by the year 2000. Reserves are estimated at 193.8 million tons, constituting 26.5 percent of world reserves. The mining sector also extracts coal, iron, gold, silver, molybden, iodine, oil, and saltpeter.

1.58 The country's mining sector can be divided into three broad groups. The first group comprises the large scale government mining operations, including four major copper mines of government-owned CODELCO, which in 1993 accounted for 56 percent of production. The second group comprises large private, mostly foreign owned, operations. Most sectoral growth occurs in this group and copper production of the private sector is expected to triple until the end of the decade (from 0.9 to 2.3 million tons). The third group comprises small scale private mining operations. Most large copper mines operate their own smelters for concentrating the copper ore. Government-owned ENAMI operates two additional smelters, which are supplied with ore from smaller mines that do not operate an own smelter.

1.59 The mining process makes polluting materials that were previously bound in solid rock accessible to air and water resulting in the emission of dust at the mining site. Depending on the grade of the ore, the tailings, or the waste left behind after the desired substances are removed from the ore, constitute more than 98 percent of the ore. Contaminants in the tailings include sulfur, which forms up to one-third of the ore, arsenic, and heavy metals. Where tailings are contained in tailing ponds, environmental damage can occur through acidic drainage and leaching of heavy metals into soil and groundwater. Additional risks are present in areas with seismic activities that can endanger the stability of tailing dams. Where tailings are directly released into the environment, local waterways are polluted with sulfuric acid, arsenic, and heavy metals. Finally, the smelters, which concentrate the ore, are an important source of air pollution with SO_2, arsenic, and particulate matter.

1.60 Pollutants that are present in mining sector emissions have been linked to health damages in humans, including respiratory diseases from particulates and sulfur oxides. Arsenic is considered to be a potential carcinogen. Damages in the agricultural sector are reported as the result of air and soil contamination. Water pollution from the mining sector, if not controlled, can cause damages to the fishery and tourism sectors.

1.61 Historically, production and investment targets were put ahead of environmental considerations in Chile's mining sector. As a result, there was almost no control of pollution from the mining sector, and sulfur dioxide, particulate, and arsenic pollution is a serious issue at all smelters. In terms of quantity of emissions, the mining sector is the most significant source of industrial contamination in Chile. In the case of SO_2, copper smelters were emitting a total of 874 thousand tons per year, which constituted 92 percent of all fixed-source SO_2 emissions in Chile in 1989 (Solari, 1992).

Table 1.5: Selected Mining Sector Sites

Name, Owner, Location	Product. (1993)	Sulphur Fixation (1991)	Area Contamination	Decontam Plan
Chuquicamata, CODELCO, Region II, copper mine and smelter	617 KT	32%	Declared saturated with PM-10 and SO_2	Approved
El Salvador-Portrerillos, CODELCO, Region III, copper mine and smelter	84 KT	2.8%	Saturated with SO_2	
Andina-Saladillo, CODELCO, Region V, copper mine	134 KT	n/a		n/a
El Teniente-Caletones, CODELCO, Region VI, Copper mine, and smelter	305 KT	5.7%	Declared saturated with SO_2	To be submitted in 1994
Paipote, ENAMI, Region III, copper smelter		31.7%	Declared saturated with SO_2	Submitted
Ventanas, ENAMI, Region V, copper smelter		54%	Declared saturated with SO_2	Approved
Escondida, BHP, Region II, copper mine and smelter	389 KT	n/a		
Disputada-Chagres, EXXON, Region V, copper mine and smelter	182 KT	74.9%	Declared latent with PM-10 and SO_2	
Mantos Blancos, Angloamerican, Region II, copper mine and smelter	75 KT	n/a		
CMP-Huasco, CAP, Region III, iron pellet plant	Contamination of Chapaco Bay with iron and quicklime; air pollution with dust and metal particles.			
Region IV, gold and silver mining	Mercury contamination of Rio Elqui, Coquimbo and Herradura Bay.			
Lota, Coronel, Lebu, Region VIII, coal mines	Acid and salt pollution of Bay of Arauco and Carnero.			

Sources: CODELCO, Ministry of Mines, Solari (1992), Huepe and Sanchez (1994).

High levels of arsenic have been measured in potable water, soils and air in the north close to mining activities. However, since natural background concentration of arsenic is high in these areas, not all concentration can be attributed to the mining sector.

1.62 Several large copper mines are located in the desert-like and relatively sparsely populated north, among them the mining complex at Chuquicamata, the new Escondida mine, and the mine at El Salvador. In the north, water consumption and water pollution by the mines aggravate the water scarcity and impact on oceanic life. In the case of ENAMI's Paipote smelter, there is strong opposition among the local population against pollution from this operation.

1.63 CODELCO's Salvador copper mine used to discard its tailings into the Rio Salado, seriously damaging flora and fauna and making the Bay of Chañaral unusable for fisheries as well as tourism. The contamination at Chañaral resulted in a law suit, in which CODELCO was ordered by the courts to cease discharge of tailings and, in 1990, install a tailing dam at a cost of US$21 million. Now, all major copper mines are equipped with tailing dams. In compensation for past environmental damages, the Ministry of Mines is supporting a development program for diversified economic activities in the Chañaral area. The feasibility of a clean-up of the Chañaral area is being assessed under the Environmental Institutions Development Project.

1.64 Closer to population centers, mining sector pollution has the potential to create larger damages. The mines and smelters in the central part of the country, including Ventanas, Chagres, and El Teniente, are located closer to the population centers. These operations contribute to the important air and water pollution problems of this region. Santiago's residents are particularly concerned about the emissions from CODELCO's El Teniente smelter because of its proximity to the city. However, recent preliminary research shows that this smelter does not contribute in a major way to air pollution in Santiago.

1.65 Starting in 1989, the government has become serious about addressing the pollution problems of the mining sector. In 1991, an Environmental Unit was established in the Ministry of Mining. The two key components of the government program are the introduction of mandatory Environmental Impact Assessments (EIA) for new operations and the implementation of decontamination plans for existing mines and smelters.

1.66 The first key component of Government policies to improve environmental performance of the sector was the introduction of a mandatory Environmental Impact Assessment for new operations. While some private sector companies have filed EIAs before they became mandatory, this requirement now applies universally to all new private and public sector projects. Between 1990 and 1993, the EIA process was applied to eight new projects with total investments of more than US$1.5 billion. Several EIA's have been approved subject to additional environmental improvements. One project proposal has been rejected for the proposed location.

1.67 As a result of the government policies, recently approved and future mining projects are expected to have much lower pollution emissions than the existing old, mostly government-owned, mining operations. The modern and inherently cleaner technologies used in new projects imply that the incremental costs for environmental protection in new mining investments are difficult to estimate, but investors generally consider them to be only a minor part of total costs.

1.68 The second key component of the Government strategy addresses pollution issues in existing operations where the control of environmental contamination is very costly. Following negotiations between the government and the industry, the Ministry of Mining issued Decree No. 185 in 1992 (Decreto Supremo No. 185). This decree determines ambient air quality standards for SO_2 and particulates and requires the development and implementation of decontamination plans for saturated areas (areas where ambient standards are exceeded). The decontamination plans have to establish measures that lead to compliance with ambient standards within a specified time. Decree No. 185 also mandates the installation and operation of air quality monitoring networks by the mining operators. According the current measurements, the areas of all five major CODELCO and ENAMI smelters are saturated for SO_2.

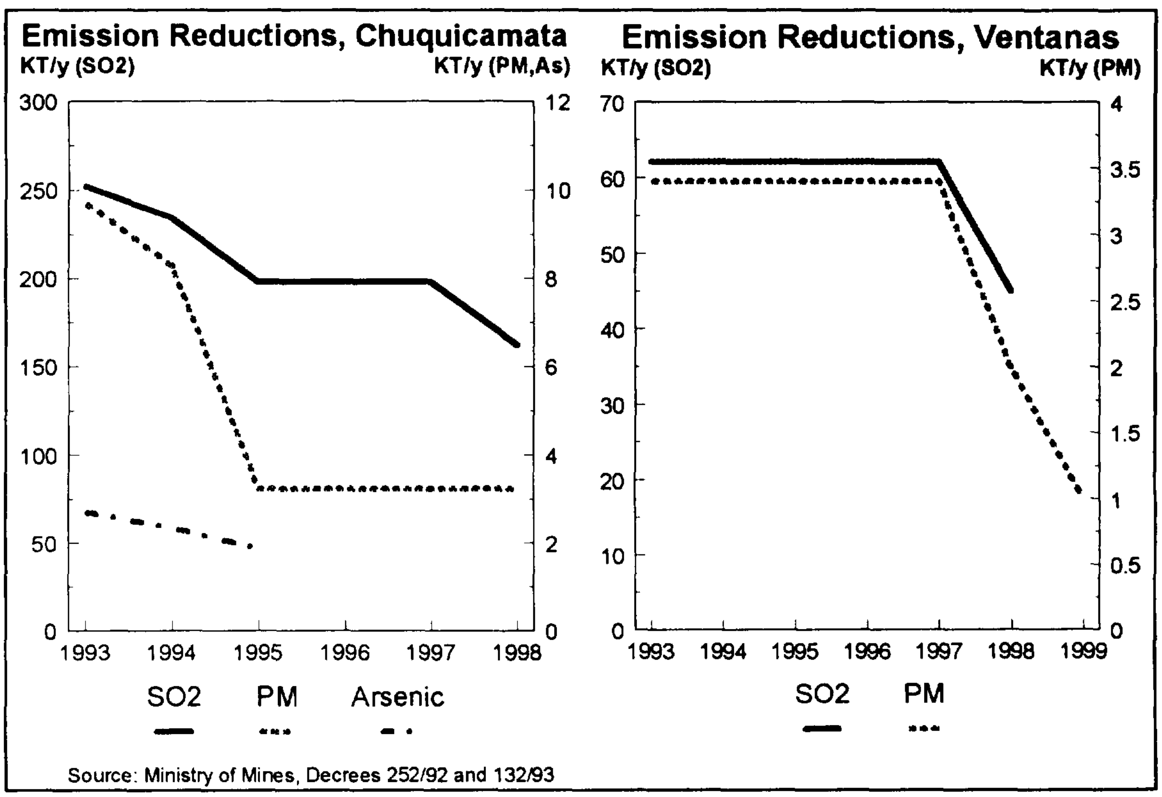

Figure 1.2 Approved Decontamination Plans

1.69 Decontamination plans have been filed and approved for Chuquicamata and Ventanas. The decontamination plan for Ventanas also covers the neighboring coal fired powerplant operated by Chilgener SA. Under the approved decontamination plans, compliance with ambient SO_2 and particulate standards will be achieved by the end of 1999 (see Figure 1.2). A decontamination plan has been filed for Paipote and is awaiting approval. The decontamination plan for El Teniente is expected to be filed during 1994. Since there are no settlements other than the workers' camp near the El Salvador/Portrerillos smelter, in this case it is planned to move the camp away from the smelter instead of developing a decontamination plan. A list of major mining operations and the status of decontamination plans is shown in Table 1.5.

1.70 The implementation of Decree 185 implies a significant commitment of resources to environmental improvements. Large investments are already underway with completion expected before the year 2000. The total costs of implementing the decontamination plan at Chuquicamata are estimated around US$400 million. The costs of the decontamination plan at Ventanas are estimated around US$40 million. The total costs of environmental investments at CODELCO and ENAMI, primarily for the construction of sulfuric acid plants for the smelters, are estimated to reach US$1 billion for the period 1992-2000. These costs ultimately imply a significant net burden on government budgets. The average annual costs of the decontamination plans (US$110 million) constitute 4.4 percent of the value of CODELCO's copper production in 1992 (US$2.5 billion), or 21 percent of CODELCO's contribution to the government budget (US$516 in 1992, excluding contributions to the Copper Stabilization Fund), or 1.5 percent of total government expenditures in 1992.

1.71 The increasing attention of the government to pollution problems in the mining sector is mirrored in improvements of the environmental management in the industry. Foreign investors tend to import technologies that meet common international environmental standards. Most large international companies have implemented tight corporate policies on environmental matters, and initiatives for environmental control have sometimes been taken by these companies before they became mandatory in Chile, either in expectation of tightening formal regulation or as a result of pressures in the home countries of foreign companies. Also, CODELCO is now taking actions to more systematically integrate environmental concerns with its operations. CODELCO has recently appointed a manager for environmental affairs and is establishing units for environmental management in its operation divisions. CODELCO is also drafting corporate environmental policies and implementing environmental training and auditing programs.

1.72 There is almost no information available on the environmental impact of small-scale mining. The environmental damage by small-scale miners that do not apply standard measures for environmental protection is potentially significant. For example, the tailings from many small-scale mines are released directly into the local waterways. The extent of pollution from small-scale mining, its impact, and possible policy options for addressing the problems require urgent study.

1.73 With the EIA system for new investments and the requirement to implement decontamination plans for existing operations, the government has created a suitable framework for addressing the most urgent pollution problems in the mining sector. Continuing government commitment will be required for the implementation of these policies. Among the outstanding tasks, agreement among the involved agencies on a realistic policy on arsenic emissions ranks high on the agenda (as of early 1994, there was still no ambient standard for arsenic in place).

1.74 Even after implementation of the decontamination plans, the large smelters will remain significant emitters of SO_2, particulate matter and arsenic (albeit within ambient quality standards). A detailed economic analysis of policies to reduce mining sector pollution beyond the steps contained in the decontamination plans for saturated areas would be desirable. Similarly, future economic analysis should be used to guide the strength of the requirements imposed in the evaluation of EIAs for new projects.

F. Other Pollution Problems

1.75 Domestic Solid Waste. Chile produced 2.4 million tons of domestic solid waste in 1988 (0.64 kg/person per day). Waste generation is unevenly distributed: the Metropolitan Region generates 60 percent of domestic waste with 40 percent of the population. Between 1980 and 1988, domestic waste increased by 7.3 percent per year. For the disposal of solid wastes, Santiago uses sanitary landfills, which have been evaluated as adequate; however, the existing landfills are expected to close at the end of 1994. The establishment of new landfill sites causes external costs including the depreciation of surrounding property values. The costs of a new landfill for Santiago are estimated at US$20 million with an increase in disposal and transport costs between 25 and 30 percent (Durán, 1992). Currently, the costs of domestic solid waste disposal are in the order of US$15/t for collection and transport and US$5/t for disposal. A part of the cost of solid waste disposal is recovered from households through a flat fee as part of the property tax.

1.76 The pressure from increasing generation of solid wastes and increasing costs of its disposal focus attention on strategies for reducing wastes. These strategies include proper pricing of waste disposal and material recycling. Increased attention should be paid to pricing waste disposal at its full social cost. Proper pricing of waste disposal, however, creates incentives for illegal dumping. These perverse incentives can be avoided if preemptive disposal charges are levied on the original products and partly refunded if safe final disposal can be documented.

1.77 In Chile, recycling is an important business. A recycling rate of 52 percent for cardboard and paper exceeds the corresponding rate in industrial countries. Glass and plastic are also recycled. About 30,000 people in Santiago are estimated to make a living from collecting recyclable material; an additional 12,500 people find formal employment in the recycling industry. It will be challenging to maintain these high levels of material use efficiency, as incomes and the opportunity costs of labor will increase. Rising wages and declining cellulose prices have already reduced the amount of low-value paper products that are collected for recycling.

1.78 Industrial Solid Waste. It is estimated that total industrial solid waste at the end of the 80s was more than one million tons per year plus 600,000 tons of sludge (Durán, 1992). Some industrial solid waste is collected by the municipal collection system for domestic waste. The majority of industrial solid waste disposal is in the hands of the private sector. The producers of industrial solid waste contract directly with private sector firms which deliver solid wastes to one of the landfills. In the SMR, a system of declaration of industrial solid wastes is established that contains the quantity and type of waste as well as its final disposal. The problem of undeclared wastes and the still existing illegal solid waste dumps requires additional detailed analysis. Again, preemptive charges on waste generators should be included as one option in the evaluation of policies to address the problem.

1.79 Toxic and Hazardous Waste. Information on the levels of toxic substances is limited. The quantity of hazardous waste was estimated at 130,000t per year in the late 1980s (Durán, 1992). The management of toxic substances and hazardous waste has so far received relatively little attention in Chile. The regulation of toxic and hazardous waste management is incomplete; however, regulation that would fill this void is currently under preparation.

1.80 Noise (acoustic pollution). Urban noise pollution is caused primarily by dense traffic. Loss of hearing is the most severe health consequence of noise pollution, followed by minor hearing problems, sleep disturbances, and stress. A previous study (BKH Consulting Engineers, 1992) estimates that in Santiago 1.5 million people suffer from health problems due to high noise levels. About 100,000 persons are exposed to noise levels considered acutely dangerous. 65 percent of residential and mixed-residential districts are above the threshold for residential use according to noise criteria used by the responsible US agency. Existing noise regulation includes Decreto No. 286/84 of the Ministry of Health and Decreto Supremo No 745/92. Work on tightening noise standards for mobile sources is ongoing.

G. Energy Sector Issues

1.81 Energy consumption in Chile has grown steadily in line with the growth of the economy. Final energy consumption is divided between industry and mining (39 percent), households and commercial enterprises (30 percent), and transportation (31 percent). Growth in energy consumption is highest in industry and mining. As significant investments in the energy intensive mining industry are currently underway, further significant increases in energy consumption can be expected in this sector. Chile's resources are significant for lignite but limited for oil and gas. Renewable resources contribute 31 percent to total primary energy consumption (fuelwood 21 percent, hydropower 9 percent). The development of primary energy consumption during the last 10 years is shown in Figure 1.3.

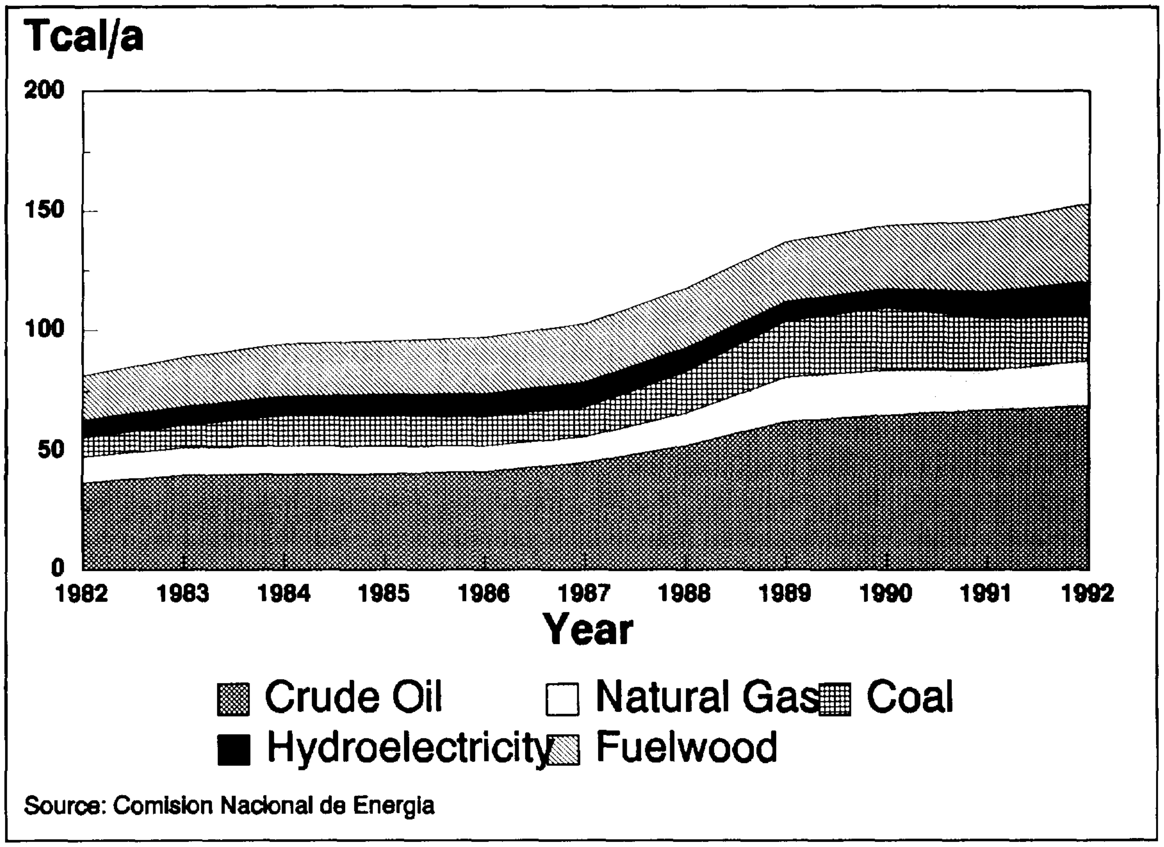

Figure 1.3 Primary Energy Consumption, 1992-1993

1.82 Electricity consumption rises at a rate higher than total energy consumption. Power generation is associated with environmental effects of thermal and hydroelectric plants. Most electricity is produced from hydropower (51 percent), coal (28 percent), oil (11 percent), and fuelwood (6 percent). Air pollution from thermal power plants is currently not a major concern at the national level, for example compared to pollution from the mining sector. However, power generation causes regional air pollution in Renca (Metropolitan Region; however this power plant is currently out of operation) and Ventanas (Region V). Total SO_2 emissions from thermal power plants are estimated at 100 to 120 million tons per year. Thermal power plants are a significant contributor to CO_2 emissions, which contribute as greenhouse gases to global warming. (The latter problem is discussed separately.)

1.83 Chile is developing large hydropower resources, which will help limit its dependence on imported oil and reduce additional air pollution. Chile has significant untapped hydro potentials that can be used to meet increasing energy demand. Hydropower, however, is not without environmental problems of its own, and the expansion of the country's hydroelectric generation capacity has caused a strong public debate in the context of the IFC cofinanced Central Pangue Dam on the Bío-Bío River. Even though the surface of the planned dam's reservoir (500 ha.) is small in relation to the generating capacity of 450 MW, the construction of the dam will lead to some disruption in the lifestyle of local indigenous communities and affect natural habitats as well as other water users.

1.84 The Central Pangue project is classified as Category A under the World Bank/IFC guidelines for environmental assessment. An environmental assessment has been undertaken including the identification of mitigation measures for possible negative environmental and social effects of the project. 53 people will have to be resettled according to a resettlement plan that complies with World Bank guidelines. A detailed plan has been developed for the minimization of physical and social impacts of the project in the construction period. The project will fund a non-profit organization of local indigenous groups to mitigate potential socioeconomic effects of the project. Several NGOs have criticized the project in view of the cumulative impact of possible additional hydro-projects on the Bío-Bío river. The Chilean Government has clearly stated that it will require a full environmental assessment, including cumulative impacts, of possible additional future projects on the river.

1.85 With 21 percent of primary energy consumption, biomass is an important energy source. The largest fuelwood users are the household sector (63 percent), and the paper and cellulose industry (24 percent). About 52 percent of household energy consumption is biomass, leading to severe in-door air pollution problems that are estimated to affect 40 percent of the population, predominantly the rural and urban poor. Fuelwood demand is the largest source of native forest depletion (see forestry section). Over time and with rising incomes, it is expected that the share of energy from biomass and the associated problems will decline.

1.86 Nonconventional renewable energy resources (such as biogas, wind, geothermal, and solar power) do not play a significant role in country-wide energy supply. They are, however, competitive in certain applications and have important future development potential. In remote areas, solar energy is used cost effectively on a small scale for energy users that are not connected to the national grid. In the north, the availability of cheap land and heavy machinery from the mining industry as well as high prices of alternative energy sources make power generation from wind competitive. A commercial investment in a 17 MW windfarm project in the north is expected this year.

1.87 Fuel and electricity prices in Chile are free of obvious distortions and based on marginal financial costs. As in most other countries, however, the cost of environmental damage is not included in energy prices. Also, the external damages from native forest depletion are not reflected in fuelwood prices. According to one recent study (Herendeen, 1994), the external costs of electricity generation can be very significant, ranging from 60 to 500 percent of average electricity rates for coal, 20 to 120 percent for natural gas, and 14 to 45 percent for oil. Environmental taxes differentiated by fuel type could be used to internalize environmental costs in the energy sector and create efficient incentives to electricity producers and consumers.

1.88 Thus far, none of Chile's electric utilities has adopted any major energy conservation activities. Instead, utilities' actions have been directed at increasing the electricity load by encouraging conversion from other fuels. Least-cost planning has so far been applied to the supply side only, and there is limited enthusiasm on the part of electricity companies for demand side management given the availability of additional hydro resources.

1.89 Research in energy efficiency at the University of Chile has identified significant energy saving potential in industry/mining, households, and transport. The National Energy Commission (CNE) has developed a program for increased energy efficiency that aims at reducing primary energy intensity (primary energy consumption per unit of GNP) by 10 percent during the 1992-2002 period. This program focusses on the dissemination of information, technical assistance, and the development of markets. Earlier estimates suggest that improved energy efficiency can reduce energy consumption by 20 percent in industry and mining, 10 percent in households, and 5 percent in transportation. A small technical assistance project supported by the GEF finances the introduction of energy efficient electrical drives in the mining industry in the north, where most electricity is generated by thermal plants. Another GEF pilot project has been initiated that will analyze the possibility of producing methanol from biomass as a transport fuel to replace fossil fuels.

1.90 There are several reasons to propose more active promotion of energy efficiency investments and demand-side management. First, energy utilities usually have access to more favorable credit terms than consumers and apply a lower discount rate to their decisions. Therefore, both consumers and utilities can gain if demand-side efficiency investments are financed at the utilities' lower cost of capital. Second, consumers often do not posses, the relevant information for assessing energy savings potential. Third, even the expansion of hydro power capacity will lead to increasing environmental costs as the most favorable locations have already been tapped. Under the current regime of electricity rates below full social costs, demand side management initiatives can reduce inefficient environmental damage resulting from unnecessary power system expansion.

H. Forest Management

1.91 Forest Resources. Of a total land area of 75.7 million hectares, 28.2 million hectares are unclassified (deserts, lakes, rivers, permafrost and high altitude areas). Of the classified lands, 32.1 million ha. are suitable for forestry of which 13.8 million ha. (31 percent of classified lands) are government-owned protected lands under the National System of Protected Areas (SNASPE). Of the other forest lands, 7.6 million ha are (often degraded) native forests, 6.7 million ha. are barren, deforested lands and 1.6 million ha. are plantation forests (see Figure 1.4). This land classification is based on land suitability. Since the ultimate use of land is at the owners' discretion, there is considerable uncertainty about the actual forested areas.

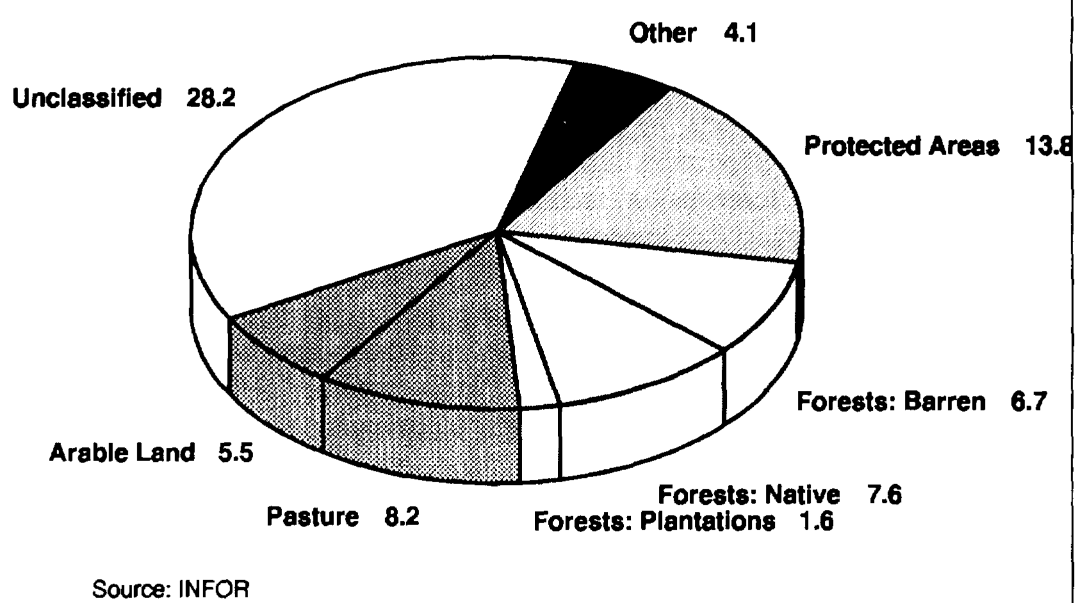

Figure 1.4 Classification of Lands in Chile (million ha.)

1.92 Even though native forests cover a much larger area than plantations, plantations are more important in terms of production (see Figure 1.5 for timber use). Excellent growing conditions, low production costs and Chile's geography with no place being far from the coast, give Chile a significant comparative advantage for the export of forest products. Most forestry revenues are generated by plantations of exotic species, principally pinus radiata. Exports of forest products have reached US$1,126 million in 1992 (about 11 percent of total exports), up from US$127 million in 1974 when the government started its plantation subsidy program. Forest product exports are dominated by pulp (47 percent of value), wood chips (14 percent), and sawnwood (10 percent). About 25 percent of forest products are exported to Japan. Over 100,000 people are employed by the forestry sector in logging, processing, and services.

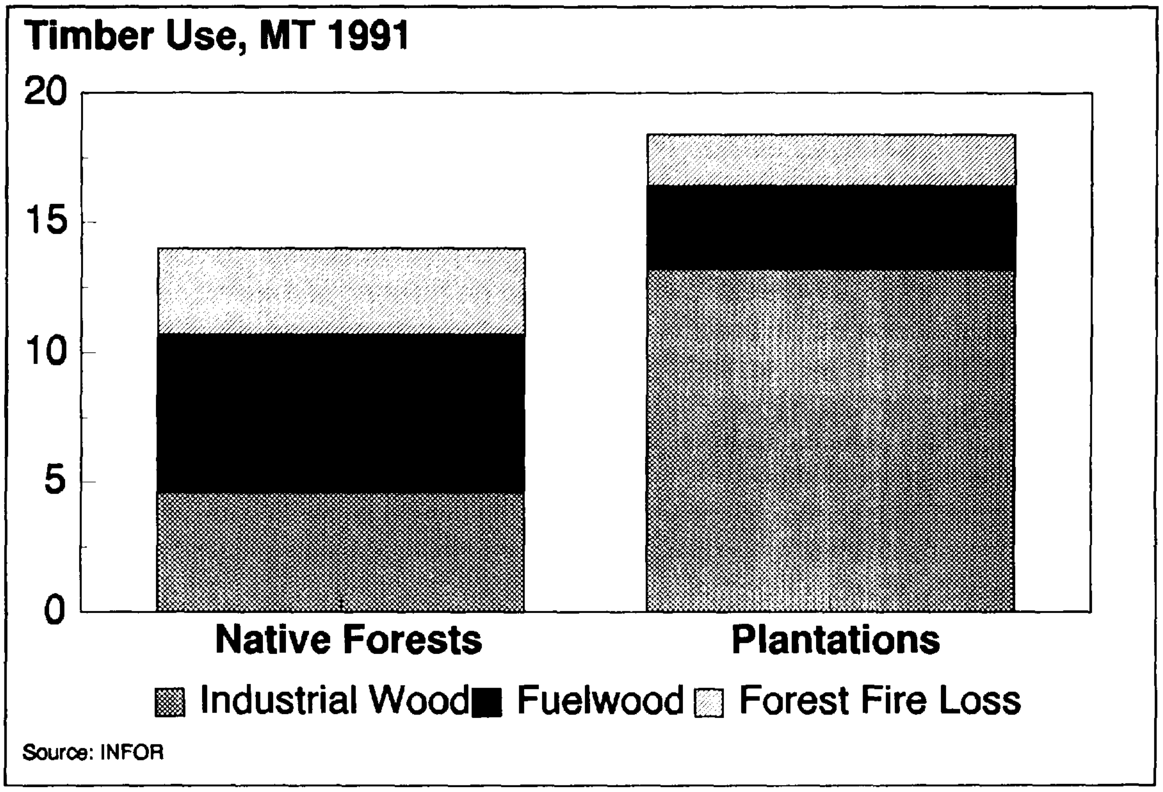

Figure 1.5 Timber Use by Forest Type

1.93 The most productive forest growing area is concentrated in the south-central part of the country (Regions VII, VIII, and IX), where the majority of plantations have been established. Conditions are ideal for eucalyptus and pine, which are well adapted and produce consistently high yields. Most of the remaining native forests, including the protected forests, are located on the slopes of the Andes and in the south (Regions X, XI, and XII). The majority of productive forest land is privately owned, both by small landowners and industry. Protected areas are state-owned and managed by the government through CONAF (Corporacion Nacional Forestal). No cutting has been allowed in these areas since the 1950's, when all concessions were banned.

1.94 The role of the public sector in forestry development was reduced significantly in the mid-1970s when most publicly-owned plantations were divested and public policies were reoriented to foster private sector initiatives. CONAF is Chile's principal forestry development and conservation institution. Its responsibilities include: (a) afforestation on government lands; (b) administration of the subsidy program for financing commercial afforestation; (c) forest fire prevention and control; (d) management of national parks, national forests and other reserves; and (e) strategic planning and policy formulation for the subsector. As a result of limited budgets, CONAF had to neglect the management of native forest areas, watershed management, and other activities that the private sector alone could not address. The government is now focussing on these neglected areas.

1.95 Plantation forestry. The rapid development of the forestry sector is based on plantation forestry, which has been substantially developed in the last two decades. In the early 1970's, private sector planting activity was negligible. Law DL 701 was enacted in 1974 to strengthen property rights and provides incentives to develop private plantations. It originally provided a 75% rebate on planting and management costs for commercial afforestation. In order to deter native forest conversion, DL 701 subsidies do not apply to areas that are currently forested or cultivated. Following implementation of DL 701, the commercial private sector became the sole force behind afforestation. Today, it is believed that plantations in many areas are commercially viable even without the subsidy. The plantation subsidy is due to expire later in 1994. Legislation currently in Congress would change the objective of the subsidy toward the protection of native forests and limit future subsidies to particular locations where plantations would otherwise not be commercially viable.

1.96 Since 1974, a total of 1.5 million ha. has been planted, bringing the total plantation area to 1.6 million ha. Pinus radiata accounts for 1.3 million ha. and eucalyptus for 0.2 million ha. of the plantation area. By 1992 annual planting had reached 130,000 ha. with about 30 percent being replanting and 70 percent new plantations. The largest share of new plantations has been developed on degraded forest or barren land. Approximately 2.5 million ha. of additional privately owned degraded agricultural land or extremely degraded forest land are suitable for additional plantation forestry and are available to industry for afforestation. Hence, pressure for the conversion of natural forest to plantation is unlikely to be caused by lack of alternative land.

1.97 The development of monoculture plantation forestry is associated with a number of environmental problems. Monocultures lead to the loss of biodiversity and are prone to disease attack, and large-scale application of pesticides is required to protect the plantations. Efforts have been made by the industry to improve the silvicultural management of plantations to retain a rich understory and provide habitat for flora and fauna. The financial and economic benefits of an increased use of native species in plantations and more diversity of exotic species have not yet been assessed. Over the last four years, the planting of eucalyptus has become increasingly popular. So far, there has been no sufficient environmental assessment of the impact of large scale eucalyptus plantations in Chile. Considering the experience of some negative environmental effects of eucalyptus plantation in several other countries, such an assessment should be given high priority.

1.98 The development of plantation forestry is creating social problems in some rural areas. Frequently, commercial enterprises are buying up lands for plantations from numerous small landowners. Lands are sometimes occupied by tenants on a sharecropping basis and owned by (absentee) landlords who do not depend on the land for their primary income. Tenants do not have a legal right to remain on the land once it has been sold. An undetermined number of people are therefore displaced. While many people find employment in the growing forest industry, others migrate to cities, increasing social pressures there. In some areas, commercial logging has led to conflicts with land claims by groups of indigenous people.

1.99 Native Forest Management. The most contentious issue in the forest sector today is the management of the remaining native forests. Even though native forests account for 83 percent of total productive forest area, their economic role is currently small and their management weak. Large areas of degraded forest land are held by small land-owners who lack the means or knowledge to manage it commercially, and who continue to gather fuelwood or leave the forest unmanaged. The present annual cut of industrial wood from natural forest is 4.6 million m^3. An additional 6.1 million m^3 is harvested as fuelwood for domestic and commercial use. There is a trend toward large industries gradually buying up the most suitable land to convert to more productive forest plantations.

1.100 Over the last few years, Chile's native forests have assumed prominence in the production and export of forest products, chiefly in the form of wood chips for the Japanese market. Wood chip production had virtually no commercial significance as recently as 1986. The harvesting of the natural forests has rapidly increased in the last seven years since large chip export facilities have been built. In 1992, 3.3 million m^3 of chips were exported with 66 percent of the wood coming from native forests. There are strong pressures to harvest the remaining commercial natural forest. It is expected that within the next eight to ten years large areas of plantations are due to mature and provide all the supply for the chipping plants as well as for other products at a much lower cost and of a much better uniformity than can be profitably extracted from natural forests. With this perspective, there are strong incentives to liquidate native forests now.

1.101 Environmental Problems. In recent years, tension has emerged between a growing conservationist movement in Chile and the commercial forestry sector. There is significant opposition to the continuing liquidation of native forests on environmental grounds. Environmental protection groups believe that the remaining native forest should be left intact to maintain biodiversity and prevent soil erosion. Potential private sector investors, on the other hand, seek to minimize government interventions that would reduce financial returns. Finally, there are those in the public and private sectors who believe that native forests can be managed in a more environmentally sound manner reconciling the objectives of conservation and production.

1.102 Chile's native forests contain several types of unique and localized forest systems including an important share of the world's temperate rainforests. Although Chile's forests are not as biologically diverse as tropical moist and wet forests, many forest ecosystems are unique to Chile. If present logging practices continue, unique plant and animal communities of these forest types would disappear. Remaining protected forest areas would be degenerated to island habitats, threatening their existence and contribution to conservation.

1.103 Soil erosion is a serious problem, with 3 percent of the country's continental surface classified as extremely seriously eroded, 18 percent seriously eroded, and 22 moderately eroded. Soil erosion causes productivity losses in agriculture as well as off-site effects from depositing silt in dams, irrigation systems, rivers and lakes. Most eroded lands are located in the central parts of the country and have not been covered with forests for a long time. However, some erosion is also caused by the recent loss of forests. Harvesting of forests and the construction of roads to remove the raw material is often an important cause of soil erosion, disruption of hydrology and deterioration of the water quality downstream. Some of the soils on which the remaining native forests are situated are fragile (composed of sandy, volcanic ash) and are highly erodible. Poor road-building techniques and clear-cutting of the forests, therefore, can lead to serious problems. Plantations are mostly located on low-lying lands, which are not subject to severe erosion.

1.104 Native Forest Policy. In theory, all harvesting activities in natural forests and plantations are controlled by the government. Management plans are prepared for each forest holding at the time of purchase. Notice has to be given of intended cutting, and principles and practices are laid out for correct harvesting procedures and subsequent reforestation. In practice, the information base on the remaining native forest as well as on actual rates of depletion is extremely weak, and the native forest continues to be cut, mainly for fuelwood and chip production.

1.105 The primary cause of environmental degradation is unregulated, illegal cutting of native forests by local people and commercial companies. Currently, there is no consistent policy with respect to the use of privately-owned natural forest. Compliance with management plans is very low since the financial incentives for continued forest management after approved cutting are insufficient. Even though there have been a few examples of companies being fined for illegal cutting, CONAF has virtually no resources to prevent illegal harvesting, ensure that proper harvesting methods are applied, or monitor implementation of forest management plans effectively.

1.106 The government is moving ahead in several areas. In 1992, Congress approved the institution of user fees, which will help strengthen the forestry service (CONAF). In addition, an institutional development program for CONAF is being developed with the Inter-American Development Bank (IDB) in the context of a proposed watershed management program. The new Basic Law affects the forests sector by requiring an environmental impact assessment for logging operations on an industrial scale. In addition a draft Native Forest Law was presented to Congress in 1992. This law has not passed as of late 1994. This Native Forest Law would prohibit the conversion of native forests, install special measures for forest protection on difficult soils, and introduce economic incentives for native forest management. The ongoing compilation of a national forestry inventory is supported by the Environmental Institutions Development Project and will provide an improved information base for forest sector policy making.

I. Protected Areas

1.107 Located on a long and narrow band west of the Andes, and isolated from neighboring countries by the desert in the north and the Andean cordillera in the east, Chile has a unique assemblage of biological communities. A count of the Chilean flora made in 1983 lists 4,758 vascular plant species in 965 genera and 190 families. While the species diversity is low compared to neighboring tropical countries, the endimicity of the Chilean flora is extremely high in many groups (see Ormazabal, 1993). Approximately 8.3 percent of the present species are considered threatened or endangered. The most critical plant conservation problem occurs on the Juan Fernandez, San Felix, San Ambrosia and Easter Islands, where some economically valuable species are already extinct. These islands contain 70 percent of the flowering plants.

1.108 Of 83 plant formations defined for the country, 54 are partially or fully represented in the Sistema Nacional de Areas Silvestres Protegidas del Estado (SNASPE), which comprises a total of 13.8 million ha. in 80 land units (30 national parks, 39 natural reserves, and 11 natural monuments). While a considerable area of Chile's national territory is protected by SNASPE, 87 percent of that is located in the Austral Regions XI and XII, which until recently with the construction of the Austral Highway, faced little threat of development. Almost 2 million ha. is made up of the San Rafael and Parque Bernardo O'Higgins ice fields. The remainder of the protected areas are small units of less than 60,000 ha. each.

1.109 Due to the territorial distribution of the protected areas, coastal, desertic, semiarid, and polar regions are poorly represented in SNASPE (Ormazabal, 1993). Some of the protected areas are of little economic value. Since population pressure is limited, there is no large scale threat to the protected areas at present. On the other hand, the acquisition of additional lands for significantly expanding the coverage by SNASPE is so far not a government priority. Recently, interest in expanding the system of protected areas has been growing.

1.110 The Chilean fauna show the same pattern of insularity as that noted for the flora, and are faced with many of the same threats. CONAF's Red Book on the land vertebrates lists 50 taxa as endangered, 92 as vulnerable, and 53 as rare. 52 of the 91 registered land mammals are under some conservation problem. Additionally, fresh water species have been hurt by pollution and the widespread introduction of carnivorous exotics, such as salmon and trout, into rivers and lakes (Arensberg, et.al., 1989).

J. Fisheries Management

1.111 With its long coastline of 4,600 km and its large exclusive economic zone, Chile has access to one of the richest and most productive fisheries in the world. The cold waters of the Humboldt stream off the coast of northern Chile support a large population of different fish species. Of the 6.6 million tons of fishery products caught in 1992, 90 percent were pelagic (open sea) species, with four species accounting for most of this catch: jurel (trachurus murphy, 49 percent), anchoveta (engraulis ringens, 19 percent), spanish sardine (sardinops sagax, 12 percent) and common sardine (7 percent). Over 90 percent of the pelagic species are processed to fishmeal and oil.

1.112 Even though the fisheries sector is still dominated by the fishmeal industry, exports of demersals (high-valued, white-fleshed fish species) and shellfish, caught predominantly off the central and southern coast, have increased significantly. Chile has also made rapid advances in aquaculture, especially in the production of salmon and trout. Chile is now the second largest aquaculture producer of salmon in the world, producing 46,600 tons annually, mostly for export.

1.113 During the eighties, the fishery sector was the fastest growing sector in Chile, growing at a rate of almost 12 percent per year between 1975 and 1989. As a result, Chile has one of the five largest fishing industries in the world. In terms of market structure, 88 percent of total capture correspond to industrial fisheries and 12 percent to small scale fisheries (see O'Ryan, 1994). Most fish products are exported, and exports of fish and fish products in 1992 were about US$1,306 million, roughly comparable to exports of forestry products.

1.114 The rapid growth of the fishery sector is reflected in heavy investments in fleet and processing equipment, and there is evidence of some over-investment in the northern pelagic fisheries. The high fishing effort results in increasing pressures on the resource stocks. Most commercially important species are now in a situation of full

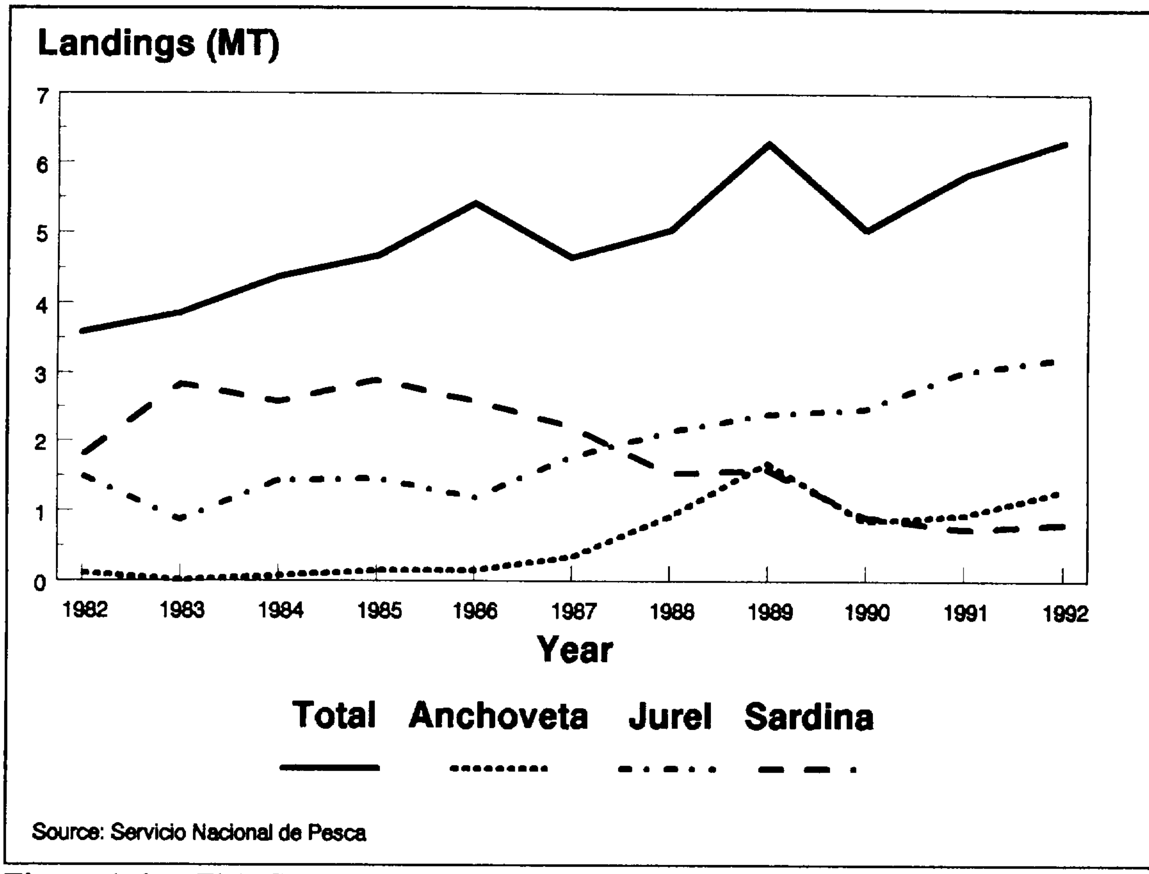

Figure 1.6 Fish Catch 1982-1992

exploitation (e.g., anchovies, jurel, and merluza commun) and some species have been overexploited (e.g., congrio dorado, and merluza del sur). Among the commercially most important fisheries, the situation is critical for spanish sardines. The biomass of this species fell from an estimated 9 million tons at the beginning of the decade to 3 million tons in 1989. As a result, the capture of this fish has fallen to around 30 percent of 1985 levels (Gomez-Lobo, 1991). Subsequent weak recruitment has further contributed to a reduction of the stock.

1.115 Traditionally, fisheries in Chile have been a common property resource with open access, and government involvement has been limited to regulation of technical aspects. In 1989, a fisheries law was passed that would have led to the universal introduction of individual transferable quotas (ITQs). Due to concerns about technical problems with the use of ITQs and political resistance from various interest groups, this law was never applied. Chile's current fisheries law (Ley de Pesca, 1991) introduced significant changes and requires the implementation of a specific management plan for every fishery in full exploitation. The instruments under the law include global quotas, controls on the number and capacity of vessels, as well as the temporary closure of individual fisheries. Under the law, ITQs are used as a management instrument for fisheries in recovery and new fisheries.

1.116 In practice, a variety of approaches have been used in the management of Chile's fisheries. Access to the fisheries in full exploitation is closed, and no additional vessels can enter these fisheries. In addition, global quotas (i.e. for merluza comun, merluza del sur, and congrio dorado) and moratoria/seasonal closures (i.e. for anchovies and spanish sardines) are imposed on some of the fisheries. Additional regulation applies to fishing technology and the minimum size of fish. For several years, a total moratorium was imposed on the catch of langostino colorado. This fishery is now under recovery and managed under ITQs. In the case of overexploited fisheries (i.e. congrio dorado, and merluza del sur), policies have been directed at improving stock assessment and diversifying fishing efforts away from these species. For the management of the northern anchovies and sardine fisheries, a convention with Peru seeks to improve cooperation in the management of this shared resource.

1.117 Fisheries are a classic open-access resource, for which, in theory, ITQs are an efficient management instrument, that should be universally applied. In practice, however, technical difficulties of enforcement and uncertainties about stock size and stock reproduction limit the universal applicability of ITQs and suggest a regime that applies a variety of management instruments. Second-best management instruments, such as global quotas or restrictions on the number of vessels, lead to problems of their own, for example the concentration of fishing efforts on a short season and the subsequent underutilization of capital and labor. After additional experience with the current regime has been gathered, a broader use of ITQs should be reconsidered, carefully taking the limitations of this management instrument into account.

1.118 The proper management of the fisheries requires careful analysis of the biological potential of the various fisheries as well as monitoring and regulation of the catch. Given the natural volatility of some species, the uncertainties about stock size, reproduction, and interactions between different species, the current situation of full exploitation of the main commercial fisheries implies significant risks. These risks can be reduced by improving the availability of data, and increasing the administrative capacity for managing the resources. Improved information and analysis is needed on the stock size and biological capacity of the fisheries, the maximum fishing effort that can be sustained, the present level of fishing effort, and its socioeconomic impact. Research initiatives would be particularly important for species that are neglected by international research because they are largely confined to Chilean waters.

1.119 Environmental Issues. Due to the length of the Chilean coastline and volatile coastal waters, coastal fishing in most areas does not suffer from contamination problems. For the fisheries sector, water pollution is only a localized problem near urban centers or industrial and mining activities. In polluted locations, heavy metal residues are absorbed in the tissue of fish later captured for human consumption. Chlorides from the pulp and paper industry and hydrocarbon pollution from refineries as well as petroleum carrying boats also affect fisheries in specific locations areas. The fisheries industry itself produces water and air pollution from fishmeal factories. The feeding of cultivated fish in lakes contributes to nutrient and organic pollution of these lakes.

K. International Environmental Issues

1.120 International Conventions. Chile is contracting party or signatory of the major international environmental conventions including the Climate Change Convention, the Montreal Protocol, the Basle Convention limiting the movement of hazardous wastes, and the UNEP South-East Pacific Convention. Chile is involved in the development of international environmental management standards (ISO 14000).

1.121 Greenhouse Gas Emissions. Carbon dioxide, methane, nitrous oxides and chlorofluorocarbons are the main substances that cause the greenhouse effect, which is expected to lead to global climate changes. Carbon dioxide emissions from the combustion of fossil fuels are the largest contributors to the greenhouse effect. The Climate Convention of the 1992 United Nations Conference of Environment and Development commits Chile as a signatory country to issue a greenhouse gas emission inventory in 1994 and submit a strategy to limit their emissions of greenhouse gases. These documents are under preparation by CONAMA and the National Energy Commission.

1.122 In Chile, annual per capita emissions of CO_2 from industrial processes are 2.42t compared to a global average of 4.21t and a South American average of 2.00t. Other than modest efforts to limit the growth of energy consumption, no effective measures have been taken so far for limiting CO_2 emissions. It should be noted, however, that Chile's plantation forests contribute to the fixation of atmospheric CO_2. Assuming that plantations absorb 17t of CO_2 per ha. per year and that CO_2 remains fixed in the final timber products, total absorption from 1.6 million ha. of plantations equals 28 million tons of CO_2 or 85 percent of CO_2 emissions from industrial processes in Chile. Based on these assumptions, Chile's net contribution to carbon accumulation in the atmosphere is very small.

1.123 Ozone Layer Depleting Substances. Chlorofluorocarbons (CFCs) have been identified as the main culprits of the depletion of the earth's stratospheric ozone layer that has potentially disastrous effects for human health and ecosystem productivity. The threat of ozone-layer depletion is particularly acute in Chile since its southernmost parts are located under the antarctic ozone hole. CFCs are also potent greenhouse gases. The main end-uses of CFCs are foams, fire extinguisher, aerosols, and refrigeration gas. Chile does not produce or export any controlled substances (CS) that deplete the ozone layer. In

Chile, per capita consumption of CFCs and halons was 0.07kg compared to a global average of 0.72kg (1990).

1.124 Chile is an original signatory to the Montreal Protocol on substances that deplete the ozone layer. Chile also acceded to the London Amendments to the Protocol and intends to phase out all CS by the year 2006, ahead of the target date for developing countries set by the Montreal Protocol for 2010 and 2015. The country program for the reduction of CS consumption in Chile was prepared by CONAMA. While changes away from the use of CS are already taking place in aerosol and fire extinguisher uses, the refrigeration and foam industry has yet to show a significant response. These industries are targeted by an Ozone Trust Fund Grant, approved in 1993. This grant provides subsidies to industries for alternative technologies, the development of an ozone seal for final consumer products, a public awareness program, and a sector-specific training program.

II. WATER POLLUTION IN SANTIAGO: HEALTH IMPACTS AND POLICY ALTERNATIVES[1]

A. Background

2.1 Surface water resources in the Maipo-Mapocho valley, which are heavily polluted by untreated domestic and industrial wastewaters from the Santiago Metropolitan Region (SMR), are used to irrigate about 130,000 ha -- including some 7,000 ha used for growing vegetable[2] crops for raw consumption in the immediate vicinity of Santiago -- resulting in atypically high rates of typhoid and hepatitis, and, more recently, an outbreak of cholera. This is not a recent phenomenon; for example, typhoid has oscillated between endemic and hyperendemic status (between 50 and 150 cases, respectively per 100,000 population) since obligatory notification was initiated in 1950, and morbidity and mortality rates were higher in the SMR than the rest of Chile. Such high rates of these communicable diseases would ordinarily not be expected in a country with the levels of income, education, health, and water supply and sanitation encountered in Chile, and particularly those of Santiago. They are, however, consistent with the widespread use of sewage-polluted water for vegetable irrigation.

2.2 News of the cholera epidemic in Peru in January 1991 reverberated throughout Chile. Given that Chile's northern neighbor had similar rates of typhoid as observed in the SMR, and the mechanisms of transmission of the two diseases are similar, with predominance of the "long-cycle" (infected individual → sewage → water pollution → food → people), it was to be expected that cholera would travel quickly to the SMR and elsewhere in Chile. Indeed, in April 1991 an outbreak began with the detection of 41 cases in April and May. Seventy percent of the cases were linked to consumption of vegetables from Santiago (Monreal, 1994). Judging by the situation in Peru, the expected consequences would include major health impacts and loss of exports. Estimated losses to the Peruvian economy in 1991 alone were $177 million in direct and indirect health costs plus export and tourism losses (WASH, 1993). An earlier cholera epidemic in

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1. This chapter was written by Carl Bartone based on the findings of background papers prepared for this study by Jose Miguel Sanchez, Ricardo Katz, Maria Benitez, Francisco Brzovic, and Juan Antonio Poblete. It also draws heavily on epidemiological research carried out by Catterina Ferreccio, with cofunding provided by the Pan American Health Organization.

2. Throughout this report, the term "vegetable" is used in a broader sense to include horticulture species susceptible to bacterial contamination by being grown in areas irrigated with polluted waters. Thus the term covers both vegetables and exposed fruits that normally come in contact with irrigation water (leafy vegetables, root crops, ground crops, berries, etc.) and commonly consumed without cooking.

Jerusalem in 1970 (Shuval, 1986), caused by sewage irrigation of 30 hectares of vegetables, resulted in some 250 cases, and nearly destroyed Israel's agricultural exports (including flowers!).

2.3 The appearance of cholera in April 1991 threatened a setback to Chile's ongoing rapid expansion of agricultural exports, which increased 64 percent over the past five years, mostly in fruit exports. The recent repercussions of two cyanide-contaminated Chilean grapes in the US market intensified this preoccupation. There was also concern for protecting Chile's image abroad so as to ensure ample opportunity for export and tourism and open the door to possible free trade agreements. In this respect, Chilean authorities were keeping a close watch on the NAFTA negotiations between the United States and Mexico and were well aware of the overriding importance attached in the negotiations to environmental conditions in Mexico.

2.4 One of the results of NAFTA was the decision to invest heavily in municipal and industrial wastewater treatment in Mexico, including almost US$ 2 billion in Bank-supported urban environmental projects. Investments of a similar magnitude for municipal wastewater treatment are also contemplated in other highly developed metropolitan areas of Latin America, and resources are already committed to initiate billion dollar investments in Buenos Aires, Sao Paulo and Rio de Janeiro over the next 10 to 15 years. There is an apparent coalescence of water pollution control objectives among the wealthier countries of the region in response to domestic demand for improved environmental quality, as well as the perceived need to maintain a competitive position abroad. A similar phenomenon is being observed throughout Eastern Europe where the Bank is supporting a long-term program to expand municipal wastewater treatment.

Existing Efforts to Control Water Pollution

2.5 The irrigation of vegetables with sewage has been prohibited since the 1967 Sanitary Code, reiterated in the Ministry of Health Resolution No. 350 of 1983, prompted by hyperendemic typhoid conditions in the SMR; however it was not until the outbreak of cholera in April 1991 that any credible action was taken. The lack of political will and the fragmentation of responsibilities for water pollution control contributed to this situation. The appearance of cholera gave a new sense of urgency and purpose to attempts to enforce regulations that have been on the books for years.

2.6 To avoid the spread of cholera in Chile, the authorities took a series of emergency actions specifically aimed at breaking the long cycle: the prohibition and removal of vegetables grown with sewage irrigation and restrictions on transporting irrigated vegetables and fruits outside of the SMR, intensification of water quality monitoring, the chlorination of irrigation water in canals, the prohibition of serving raw vegetables in restaurants, and an intensive campaign of social communication informing the population of the risks of vegetables and the need to wash and cook them. New regulations were promulgated extending prohibitions to other vegetables normally consumed crude, and field inspections were intensified. To demonstrate their seriousness, authorities bulldozed and burned 130 hectares of prohibited vegetables irrigated with sewage. The result of these energetic measures was not only rapid control of the spread of cholera, but also significant reductions in typhoid and hepatitis throughout the country and especially in Santiago.

2.7 The broader problem of controlling the municipal and industrial wastewater discharges of Greater Santiago has been recognized for some time, and in the mid-1980s EMOS undertook studies of wastewater interception and treatment. Construction of the first interceptors began in 1990 aimed at eliminating primary pollution of 12,700 hectares of irrigation in the most heavily polluted areas. Further interceptors are programmed to begin 1995. To avoid simply moving the pollution problems downstream, treatment options are also being examined, and a pilot treatment plant has been constructed and is in operation. Currently, EMOS is completing a treatment master plan. The Bank has supported all of these activities.

2.8 Institutionally, water pollution control responsibilities are divided across a number of actors. The SSA and DGA are currently responsible for ambient water quality, and SSS, SAG and EMOS are in charge of effluent related responsibilities. In addition, CONAMA has broad responsibilities for environmental management as well as policy analysis and proposals, and CEDRM was created in 1990 to solve the critical pollution problems of the SMR, including water pollution. The organizational set-up is fragmented and not conducive to the coordination of actions to protect specific water bodies or basins, nor is there a strong institution effectively in charge of monitoring water quality so as to ensure compliance. As an example, the SSA has only five environmental health inspectors to respond to some 2,000 complaints each year as well as undertake normal monitoring activities. To overcome overlapping responsibilities among institutions, ad-hoc commissions have been created to deal with the resulting political problems, but often without the required enforcement power. Regulatory agencies have little in-house research capacity; most environmental research is done by independent researchers and does not necessarily respond to the agencies' needs.

The Task Ahead

2.9 The water quality management priority for the SMR is to consolidate the gains that have been achieved in controlling cholera and typhoid as a result of the application of emergency measures. By their nature such measures depend on sustaining the cooperation of farmers and the public, as well as the political will to continue effective monitoring and enforcement. There are already signs of laxity in inspections and public vigilance. Given the magnitude of the public health risks involved, there is now a need to pursue technical and management options that could provide full and lasting public health protection. The main technical option being considered is to provide a level of wastewater treatment that will ensure compliance with Chile's water quality standards for unrestricted irrigation.

2.10 While investments in wastewater interception and treatment would effectively eliminate water pollution and irrigation reuse problems related to pathogens, they raise another priority issue the need to control industrial wastewater discharges. Chemical pollution from industrial wastewaters would pose both health and agronomic risks for irrigation reuse, could damage sewer pipes and interfere with treatment operations, and would complicate disposal of treatment plant sludge. Chile is only in an incipient stage of developing a program for pretreatment and control of industrial discharges to sewers.

2.11 Finally, the present Water Code virtually ignores quality issues. In combination with the new Basic Law on the Environment, proposed modifications to the Water Code could, if passed, create new institutional structures to deal with combined water quantity-quality problems. However, the question of water quality is not explicitly dealt with in the proposal and considerable additional effort will be required to develop a new regulatory framework for water quality management. The framework should facilitate managing relations between water uses and users at the basin level, especially with regard to environmental interactions. New mechanisms and institutions are needed to help resolve water quality conflicts, i.e., through negotiation or litigation.

B. Description of the Santiago Study

2.12 The direct cost to the Chilean economy of the health impacts of sewage irrigation in the SMR is significant, including health care costs, lost work days, and premature death. Also, there are many potential indirect costs such as the risk of multi-million dollar losses of agricultural export earnings and tourism revenues in the event of a major cholera outbreak (as has been observed as a result of cholera outbreaks in Israel and Peru, and in the recent case of "cyanide-contaminated" grapes involving Chile and the US).

2.13 Against the potential benefits of reducing these impacts, the costs of interventions must also be considered. Past inaction has resulted in part from failure of authorities to properly measure and weigh the corresponding benefits and costs. It has been assumed that sewage treatment or other interventions are too costly, that there is little willingness to pay on the part of water consumers or society to meet environmental goals, and that the conflict between urban and rural use of water and land in the region is too politically sensitive to resolve. This study seeks to contribute to a broader view of these issues and help inform the debate that is now underway in Chile prompted by the cholera threat.

Objectives

2.14 This study is one of three carried out to demonstrate how quantitative methods can assist in the analysis of a discrete environmental problem and inform policy decisions. As such, it is limited in scope: the focus is exclusively on the health impact of microbiological water pollution in the SMR. The objectives of the study are to examine the magnitude of the direct health impact of the use of contaminated water for irrigation in the Santiago Metropolitan Region (SMR). The estimates of the health impact of irrigation-linked diseases and the associated economic costs then will be compared to the economic costs of alternative policy options including:

- full or partial municipal wastewater treatment;
- treatment of irrigation water prior to use;
- development of alternative clean irrigation water sources;
- changed agricultural practices; and
- modified consumer behavior.

2.15 The efficiency and effectiveness of both long and short-term measures will be assessed, together with the regulatory and institutional framework in which they are to be implemented. The goal is to propose cost-effective solutions to the problem of reducing health impacts while still providing vegetables and other fresh produce at reasonable prices.

Methodology

2.16 Typhoid and paratyphoid, and to a lesser extent hepatitis, are known to be causally linked to sewage irrigation and have for decades been endemic in Chile. The typhoid model is particularly appropriate for study since it is very similar to cholera -- both are transmitted mainly by the long cycle (infected individual → sewage → water pollution → food → people). Other enteric diseases such as common diarrhea and parasitosis, while also transmitted in part by the long cycle, have a short cycle of transmission (excreta → hand → mouth) and do not serve as good models for this study. While the number of episodes of diarrhea and parasitosis attributed to the long cycle would probably surpass cases of typhoid and hepatitis attributed to that route, there is a lack of complete and systematic information about the former diseases and it is not possible to determine their evolution in time. The only information available is about diarrhea deaths, particularly infant deaths, but diarrhea mortality has been brought under control by existing environmental health policies. Therefore, the typhoid model is used to estimate the degree of association between health outcomes and sewage irrigation, and to estimate direct health costs and extrapolate them to cholera. For the direct costs of morbidity the cost-of-illness approach is used, and for mortality, the human capital approach.

2.17 Five separate analyses were initiated to meet the objectives, all of which are characterized as "desk studies." The analyses include the assessment of epidemiological linkages between water pollution and health impacts, three economic valuation studies of health impacts, intervention costs and farm profitability impacts, and an analysis of the regulatory and institutional framework for water quality management in Chile. The general approach taken compares the costs and benefits associated with the various policy options and interventions for reducing the health impacts of sewage irrigation around the SMR. The options studied are those described in the objectives section above. Distributional effects are also considered as costs and/or benefits will accrue to both the community at large whose health is affected as well as to the farmers who depend on wastewater for irrigation supply. In addition, the study assesses the institutional feasibility of implementing needed policies and interventions.

2.18 Epidemiological Linkages between Pollution and Health Impacts. The only reliable time-series data in Chile on morbidity from enteric diseases related to water pollution are for typhoid and paratyphoid fever and infectious hepatitis. A convincing case built on circumstantial evidence has been made to link the problems of typhoid-paratyphoid in the SMR to sewage irrigation via the long cycle. To a lesser extent infectious hepatitis may also be linked to sewage irrigation. Time-series data from the Ministry of Health indicate that the emergency measures taken recently for cholera prevention also contributed to a significant reduction in these diseases during the summer of 1992. Through statistical analysis of these data and existing epidemiological studies it should now be possible to establish the pollution-irrigation-health linkages as well as to assess the relative effectiveness of interventions taken. Specifically, this analysis is aimed at:

(a) comparing time-series data on typhoid-paratyphoid and hepatitis morbidity and mortality within the SMR and the rest of Chile for the period 1985-92;

(b) evaluating the impact of diverse emergency interventions and other events on patterns of occurrence of typhoid-paratyphoid and hepatitis;

(c) assessing the occurrence of water-related diseases in populations of farm workers and local residents in areas irrigated with highly polluted water; and

(d) quantifying the impacts in terms of measures such as, lost work days, restricted activity days, health treatment costs, hospital costs, years of healthy life lost, and averting actions at the household level.

2.19 Economic Valuation of Health Impacts. This analysis assesses the existing and potential direct economic impacts on human health that result from sewage irrigation in the SMR, as well as other indirect costs such as productivity losses and potential risk of export earning losses. Using the direct measures of health impacts provided by the epidemiological study of the typhoid model, this work extrapolates the results to cholera, refines the estimates of economic costs of pollution-related health effects due to health care, preventive measures and lost productivity, and incorporates estimates of other defensible indirect costs related to perceived health risks.

2.20 Economic Valuation of Intervention Costs. This substudy assesses the implementation costs associated with the policy options and interventions for prevention or reduction of disease transmission. These costs are estimated at the prefeasibility level using standard project evaluation techniques. Complementarities or conflicts between options are also evaluated. Also, a qualitative assessment is made of the effectiveness and effort associated with each of these options. An analysis of issues related to the impacts and control of industrial discharges is also included.

2.21 Economic Valuation of Farm Profitability Impacts. Whatever the proposed policy options and interventions for reducing the health impacts of sewage irrigation around the SMR, the corresponding economic impacts at the farm level need to be assessed in terms of changes in productivity and income. The past two years have witnessed the imposition of emergency cholera control measures, and increasing efforts to define sewage treatment and reuse strategies that could result in reduced water availability in traditional irrigation areas. Resulting shifts in irrigation water sources, cropping patterns, crop production, and market prices are identified and estimated from existing data for selected irrigation areas and extrapolated to the broader region. The substudy also seeks to estimate farmer willingness to pay for better quality water.

2.22 Regulatory and Institutional Framework for Water Quality Management. The final substudy focuses on the regulatory and institutional framework and its implications for water management and water pollution control in the SMR and the broader Maipo-Mapocho Basin. The past few years have witnessed major regulatory and institutional changes in the water sector in Chile, principally in the water supply and sewerage subsector. Policies aimed at the creation of water markets and river basin corporations are also being studied. A draft law now in parliament and the new Basic Law on the Environment would significantly modify environmental and water resources policies in Chile. The resulting or expected implications for policy coordination, choice of policy instruments, institutional development and conflict resolution are discussed as they relate to the Maipo-Mapocho Basin.

2.23 Results. The results of these substudies are presented in a number of background papers. The first is an analysis of the epidemiological linkages between water pollution and health impacts in the SMR (Ferreccio, 1993). Also, economic estimates are provided of the costs of health impacts (Ferreccio, 1993; Sanchez, 1993), farm-level impacts of water pollution control interventions (Brzovic, 1993), and the cost of interventions (Katz and Benitez, 1993). The final background paper is on the regulatory and institutional framework for water quality management in Chile (Poblete, 1993). The main findings of each of these papers are summarized below.

C. Water Pollution and Health in the SMR

2.24 The pattern of enteric diseases in Chile is unique. As a country with moderate income, high levels of education, nutrition and health care, ample coverage with good quality water supply and reasonable sanitation (over 90 percent of the SMR population connected to sewerage), the indicators for enteric diseases would be expected to be low. This is in fact the case for classic indicators such as infant diarrhea, infant mortality, and parasitosis. Two diseases, however, remained at endemic levels: typhoid and paratyphoid fever and infectious hepatitis. These are also the only enteric diseases of obligatory notification for which reliable time series data are available at the national and local health service levels. The substudy focuses on these two diseases and seeks to identify the epidemiological associations between these two diseases and water pollution in the SMR.

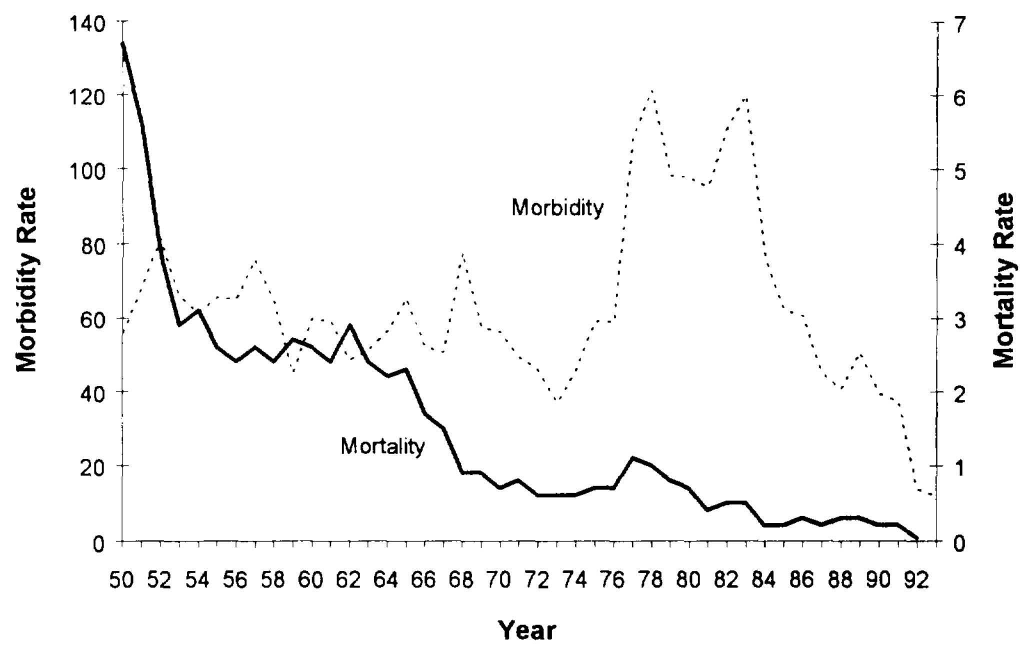
Typhoid Fever

2.25 Typhoid and paratyphoid fever[3] has been endemic in Chile with high annual morbidity rates, in excess of 50 cases per 100,000 population since obligatory registration was initiated in 1950. Mortality steadily declined during the period 1950 to 1990 from 6.7 to 0.2 per 100,000. Both the morbidity and mortality times series for Chile from 1950 to 1993 are shown in Figure 2.1. Typhoid exhibits a clear seasonal variation with more cases occurring in the summer months and coinciding with vegetable harvesting periods. Historically, the incidence of typhoid has been greater in the SMR than the rest of the country, this despite the SMR and its capital city, Santiago, being the center of economic and social development in the country.

2.26 In the SMR, typhoid has exhibited hyperendemic years (with an abnormally high number of cases in excess of 150 per 100,000), endemic years, and "normal" years. Furthermore, seasonal variations have been much greater than in the rest of Chile. The majority of cases occur in summer months, while in the winter the disease practically disappears.

3. Commonly called "typhoid fever," typically about three-fourths of the cases in Chile are caused by *Salmonella typhi* and the rest by *S. paratyphi B*. Cases of *S. paratyphi A* are not common.

Figure 2.1: Typhoid Morbidity and Mortality in Chile, 1950-93 (Rate per 100,000 Population)



Infectious Hepatitis

2.27 Viral hepatitis has the highest rates of all diseases of obligatory notification in Chile. Between 1960 and 1990 incidence rates increased steadily, stabilizing around 1984. Mortality remained stable and low throughout the same period. Over 80 percent of the cases are caused by viral *Hepatitis A*. Rates are higher in the extreme northern region of Chile, with intermediate rates in the SMR. In contrast to typhoid, hepatitis has higher rates in the cold months and affects younger ages more.

Mechanisms of Transmission

2.28 The classical mechanisms of transmission of enteric diseases are poor personal hygiene or the "short cycle" (excreta → hand → mouth), and environmental pollution or the "long cycle" (infected individual → sewage → water pollution → food → people). As pointed out above, the short cycle of contagion has been significantly reduced in the SMR. This is confirmed by the reduction in infant diarrheal mortality. It appears that control of the short cycle has also contributed to lower rates of hepatitis in the SMR compared to the rest of Chile. On the other hand, the prevailing mechanism for typhoid transmission in the SMR appears to be the long cycle. Circumstantial evidence has long supported this argument, and the substudy verifies it.

2.29 The causal agent of typhoid fever (*Salmonella typhi*) has been isolated directly from irrigation water in the SMR. Although viral *Hepatitis A* has not been similarly isolated, there are numerous reports in the scientific literature of viral hepatitis isolation from water sources (rivers, lakes and seawater). Thus, the sewerage system, the use of sewage for irrigation, and the types of crops grown taken together present the material conditions for long-cycle transmission.

2.30 The occurrence of typhoid fever increases seasonally in the SMR following the summer pattern of increase in sewage irrigation and the rise in consumption of raw vegetables. In contrast, hepatitis decreases during this period and increases in the winter, when irrigation is minimum and personal contact is maximum.

2.31 Disease transmission by environmental pollution normally exhibits cyclical changes depending on climatic factors such as rainfall, which in the SMR presents dramatic annual variations. The period of typhoid hyperendemicity coincided with a sequence of dry years during which sewage irrigation intensified.

2.32 There have been two interventions aimed at breaking the long cycle, which can be characterized as natural experiments that provide the opportunity to measure the impact of interventions on the incidence of disease. During the period 1976 to 1984, the typhoid rates in the SMR reached the highest levels ever registered, up to 215 per 100,000 in the SMR. In 1984, the health authorities prohibited the cultivation of vegetable crops consumed raw, and initiated a public education campaign on the risks of sewage irrigation for health. From 1983 to 1985, typhoid was observed to drop 59 percent and hepatitis fell 11 percent. By 1986, typhoid had dropped from hyperendemic levels to a situation of average endemicity. (It should be observed that a prolonged dry period also ended at the same time, reducing the need for sewage irrigation and providing greater dilution of sewage in rivers and channels.)

2.33 The second opportunity to test this hypothesis occurred as a result of the cholera outbreak in South America. To avoid the spread of cholera in Chile, the authorities took a series of actions specifically aimed at breaking the long cycle: the prohibition of vegetables grown with sewage irrigation, the prohibition of serving raw vegetables, and an intensive campaign of social communication informing the population of the risks of vegetables and the need to wash and cook them. The substudy aims at measuring the impact of these interventions.

Comparing Typhoid Fever and Hepatitis in the SMR and the Rest of Chile

2.34 To compare typhoid and hepatitis in the SMR and the rest of the country during the period 1985 to 1992, ARIMA models were developed for the corresponding time series data. The 95 percent confidence band for 1986 was used to provide a basis of comparison for the other years in the series. For typhoid fever, these comparisons showed that cases in the SMR in 1991 and 1992 dropped below the minimum expected number of cases and demonstrated statistically an external alteration in relation to the historical series. The same comparisons of the time series for the rest of Chile revealed a significantly lower reduction than for the SMR.

2.35 Similar comparisons for hepatitis showed that cases in the SMR for 1991 and 1992 also fell significantly below expected minimums, but the fall was less notable than that observed for typhoid. For the rest of Chile, the reductions observed in hepatitis cases were equal to those observed for typhoid.

2.36 The annual rates for these diseases in the SMR and the rest of Chile were also subjected to statistical comparisons. From 1985 to 1991, typhoid rates in the SMR exceeded those in the rest of Chile, and in 5 of the 7 years the differences were significant at the 95 percent level using the Chi Square test. In 1992, for the first time the typhoid rate in the SMR (8 per 100,000) fell below that for Chile (18 per 100,000). Hepatitis rates for all years were lower in the SMR than in the rest of the country, being significantly lower in 3 of 8 years. Comparing typhoid rates to hepatitis rates, in the SMR typhoid was significantly lower in 4 of 8 years and indistinguishable in the other years, while for the rest of Chile hepatitis was always significantly higher.

2.37 From this analysis, several conclusions can be drawn:

(a) the interventions taken at the time of hyperendemic typhoid (crop restrictions and public education campaigns) and the package of emergency interventions imposed at the time of the cholera threat proved effective in significantly reducing the incidence of typhoid, although in differing degrees;

(b) infectious hepatitis cases also fell, but not to as great an extent, as this disease is also transmitted by the short cycle;

(c) cholera, initially concentrated in the SMR and affecting all socioeconomic and age groups, appeared to have spread by consumption of contaminated vegetables and also appears to have been effectively controlled by the emergency interventions undertaken in 1991; and

(d) the long cycle mechanism of transmission of typhoid and cholera, and to a lesser extent hepatitis, continues to operate but appears to have been interrupted in part by changes in the population's vegetable consumption habits and also by changes in irrigation practices for vegetables. The stability of these changes is difficult to predict.

Intervention Analysis

2.38 The interventions undertaken in 1991 were broad and intensive, including controls on irrigation water, drinking water quality, vegetable production and consumption; elimination of unsanitary conditions; and information and social communication campaigns. The effects of these measures can be seen in Table 2.1 showing the cases of typhoid and hepatitis before and after the 1991 interventions. Comparing the impact on typhoid in the SMR to the rest of the country, it appears that at an absolute minimum at least 35 percent of the cases in the SMR can be attributed to sewage irrigation. In fact, it will be shown (para. 2.42) that the share is much higher.

2.39 A multivariate analysis of pre- and post-intervention typhoid and hepatitis was carried out to measure the relative contribution of the various factors on the variations in incidence of these diseases. The model chosen analyzed the impacts of temperature, drinking water supply and "press" (a variable which includes social information by mass media and sanitary education). It was not possible to find adequate variables to reflect other interventions. Using this model, it is possible to conclude that the explanatory variable "press" is significant and explains half of the fall in typhoid fever cases. The remaining half could be attributed to direct controls on the production and sale of vegetables. The model is less successful in explaining the behavior of hepatitis, which appears to be less attributable to vegetable consumption.

Table 2.1: Typhoid and Hepatitis Before and After the 1991 Interventions
(average cases per year)

	Typhoid Fever		Hepatitis	
	SMR	Rest of Chile	SMR	Rest of Chile
Pre-Intervention, 1985-90	3,558	2,971	4,040	7,474
Post-Intervention, 1992	454	1,429	1,430	3,845
Reduction	87%	52%	65%	49%
Impact in SMR vs Rest of Chile	+35%		+16%	

Source: Ferreccio (1993).

Spatial Analysis of Typhoid and Hepatitis Behavior

2.40 Correlation analysis on the behavior of typhoid and hepatitis at the commune level was carried out using the following variables for the 51 communes comprising up the SMR: poverty, level of rurality, population density, drinking water quality, proximity to polluted canals, infant mortality, and adult mortality. From this analysis, it appears that typhoid fever is related to adult mortality and population density, while hepatitis appears associated with infant mortality, poverty and rurality. This is consistent with the hypothesis that hepatitis is mainly transmitted by lack of personal hygiene and personal contact, especially between young children, while typhoid is predominantly due to sewage irrigation of vegetables. In conclusion, what is observed at the commune level coincides with observations at the regional level that *the long cycle plays an important role in typhoid transmission, and is capable of bypassing the protections of socioeconomic development.*

Study of Enteric Diseases in Rural Communes

2.41 Clinical records were analyzed in two communes, one with intensive use of sewage for irrigation and the other with ground water irrigation. No health problems were detected that could be attributed to direct contact with polluted water. Local populations seem well aware of the health risks of contact with sewage. This is consistent with the previous observations in the sense that *typhoid is associated with the consumption of vegetables contaminated by sewage irrigation rather than by direct contact with sewage.*

Health Care Burden in the SMR

2.42 Given the success of the emergency interventions in controlling typhoid, it is now possible to obtain better estimates of the number of cases in the SMR that can be attributed to sewage irrigation of vegetables. Taking 1992 as the year representing a controlled situation (that is, without cases transmitted by sewage-contaminated vegetables), a 95 percent confidence band was constructed for the maximum and minimum expected weekly cases of typhoid for that year. The annual time series of weekly cases for the period 1985 to 1991 was compared to this band and the number of imputed cases for each year was estimated (the sum of the weekly observed cases in each year in excess of the maximum expected weekly cases in 1992). This permitted the calculation of the percent of cases attributed to sewage irrigation, yielding a range from 49 to 79 percent, as shown in Table 2.2. This is much greater than the previous estimate of 35 percent (para. 2.38).

Table 2.2: Typhoid Cases in the SMR Attributable to Sewage Irrigation, 1985-92

Year	Observed Cases (a)	Expected Cases * (b)	Imputed Cases	
			Number (a-b)	Percent
1985	4,444	935	3,509	79.0
1986	2,907	728	2,179	75.0
1987	1,180	645	535	45.3
1988	1,662	768	894	53.8
1989	2,718	877	1,841	67.7
1990	1,471	674	797	54.2
1991	1,773	517	1,256	70.8
1992	322	320	2	0.6

* The sum of the weekly observed cases falling below the maximum expected weekly cases in 1992, the control year.
Source: Ferreccio (1993).

2.43 To estimate the health care burden in the SMR, a study of the evolution and distribution of typhoid cases was carried out using 1987 household survey data. Cases can be distinguished as those which can be treated as outpatients (70 percent) and those requiring hospitalization (30 percent). These can be further characterized as simple cases, cases with complications, and cases with relapse. Taking into account these distinctions, the weighted average of restricted activity days (RADs) per typhoid case is estimated as 28.4 RADs for an outpatient case and 28.8 RADs for a hospitalized case. The latter includes 13.5 days hospitalized on average with the remainder of the time in repose at home.

2.44 In addition, the household survey revealed that the sick were taken care of by female family members, accounting for 9.2 RADs per typhoid case for in-home care plus 3.6 RADs per case for activities outside of the home, for a total of 12.8 RADs per case. Finally, the distribution of typhoid cases by age is as follows: 41.2 percent are under 15 years old; 27.6 percent are between 15 and 24; 19.5 percent are between 25 and 34; 6.7 percent between 35 and 44; 2.8 percent between 45 and 54; 1.6 percent between 55 and 64; and 0.6 percent are 65 or older.

D. Economic Costs of Health Impacts

2.45 The economic valuation of health impacts due to typhoid in the SMR is based on the quantitative measures of morbidity and mortality described above in combination with monetary measures of the unit costs of sickness and death. The direct costs considered in this paper are those related to treatment costs, the productivity costs incurred because of episodes of illness (restricted activity days or labor absenteeism) or premature death (human capital approach). These productivity costs are measured in terms of lost labor earnings. These measures do not include inconvenience, pain, suffering, commuting costs, losses in leisure or other impacts to the individual and family well being, and they seriously underestimate or completely ignore the cost of sickness of people that are not members of the work force. It is generally agreed that *valuing costs exclusively using direct treatment costs and lost labor income only indicates a lower bound of the real willingness to pay to avoid these effects and understates the total costs to individuals.*

2.46 Indirect health costs are also incurred. These include expenditures by individuals or society to avert undesirable health outcomes or risks. Other indirect health costs include losses in earnings related to reduced agricultural exports or tourism. In this section, risks associated with potential agricultural export earnings are examined. There was inadequate information to estimate tourism losses although it is a sector that is currently growing at 18 percent annually and could be significant. The costs of some measures undertaken to avert the transmission of typhoid or cholera by the long cycle are evaluated and discussed in later sections.

Direct Treatment Costs

2.47 Data on direct health costs for treating cases of typhoid fever show that in the SMR, 70 percent of cases are treated as outpatients, with an average cost of US$104 per case, including costs of medical visits, laboratory tests, and drugs. The remaining 30 percent are hospitalized with an average cost of US$798 per case including hospital bed occupancy, medical attention, laboratory tests, and drugs. These average costs take into account added costs due to complications and relapse and the proportion of cases that are treated in the public and private sectors. Overall, the weighted average cost is US$319 per case.[4]

4. These unit costs were updated from Ferreccio (1993) by Ferreccio (personal communication) based on public sector price adjustments by FONASA between 1990-92. The exchange rate used is 416 pesos per US dollar.

2.48 By multiplying this weighted average cost by the number of observed cases and estimates of imputed cases (Table 2.2), the corresponding direct health care costs for all cases and for cases attributable to sewage irrigation are calculated in Table 2.3.

Table 2.3: Direct Treatment Costs of Typhoid in the SMR, 1985-1992 (US$ '000)

Year	Observed Cases	Imputed Cases
1985	1,418	1,119
1986	927	695
1987	376	171
1988	530	285
1989	867	587
1990	469	254
1991	566	401
1992	103	1

Sources: Ferreccio (1993); Ferreccio (personal communication); Sanchez (1993).

Productivity Costs -- Morbidity

2.49 Other health costs associated with typhoid in the SMR are the losses resulting from restricted activity days or labor absenteeism. This applies both to days lost through illness as well as to days lost by women when caring for a sick family member. Information on average monthly labor income by age and gender is provided in Table 2.4. This information is obtained from the latest national CASEN survey corresponding to November 1990. It is the most comprehensive and reliable source for income and other social indicators. Since the data are from a nationwide survey, they may slightly underestimate the average monthly salary in Santiago. The data given in Table 2.4 have been adjusted to 1993 US dollars by inflating them by the Wages and Salary Index and dividing by the exchange rate of 416 Chilean pesos per US$.

2.50 Combining the income data in Table 2.4 with information on the average length of illness and the average time family members dedicate to caring for the ill (para. 2.43 and 2.44), the age distribution data of typhoid cases (para. 2.44), and the case data in Table 2.2, the associated productivity costs can be computed for the period of study, as summarized in Table 2.5.

Table 2.4: Monthly Labor Income by Age and Gender (1993 US$)

Age Group	Monthly Income by Gender		
	Men	Women	Total
15 to 24	161	151	158
25 to 34	290	223	268
35 to 44	377	245	333
45 to 54	412	248	361
55 to 64	379	223	339
> 65	383	198	338
Total	317	217	285

Source: Sanchez (1993).

Table 2.5: Direct Productivity Costs from Typhoid Morbidity in the SMR, 1985-1992 (US$ '000)

Year	Lost Income from Illness		Lost Family Income	
	Observed Cases	Imputed Cases	Observed Cases	Imputed Cases
1985	573	452	411	325
1986	375	281	269	202
1987	152	69	109	50
1988	214	115	154	83
1989	350	237	252	170
1990	190	103	136	74
1991	229	162	164	116
1992	42	0	30	0

Source: adjusted from Sanchez (1993).

Productivity Costs -- Mortality

2.51 The economic losses associated with premature deaths due to typhoid in the SMR are estimated using the human capital approach. this assumes that the value of each unit of human capital can be estimated by the present value of future output in the form of labor earnings that might have been generated had the individual not died prematurely.

2.52 The approach has a number of shortcomings; among them is the fact that deaths are valued only according to the wage income lost, ignoring pain and suffering.

The values estimated are dependent on the age of death, wage distribution, education, and skill level. For example, the very old have small human capital value when this approach is used. Additionally, other dimensions of an individual's contribution to society are excluded, such as his or her contribution to the well-being of others and non-market activities. For the Chilean case, estimates of human capital values are obtained using Table 2.4 and the life expectancy tables for Chile published by the Superintendencia de Valores y Seguros. For example, Table 2.6 gives some estimates of the present value of lost labor income for different ages of death. Note that a *social* discount rate of 5 percent is used in making these computations of human capital values.

Table 2.6: Present Value of Lost Labor Income
Because of Premature Death (1993 US$)

Death Occurred at Age	Men	Women
1 year old	26,875	21,582
42 years old	74,750	49,692
65 years old	47,163	31,885

Note: Annual discount rate used is 5%.
Source: Sanchez (1993).

2.53 Using data on the distribution by age and gender of deaths due to typhoid and paratyphoid fever in the SMR from 1985 to 1992, and applying the method described above, yields Table 2.7 for the monetary value of the mortality impacts of typhoid. *The weighted average lost income is equal to US$37,255 per death.*[5]

Total Direct Costs of Health Impacts

2.54 Estimates of the total direct costs of the health impact due to endemic typhoid in the SMR over the period 1985 to 1992 are obtained by combining Tables 2.3, 2.5 and 2.7. The results are shown in Table 2.8. During the years of endemicity (that is, 1985-90), the total cost of overall typhoid morbidity and mortality in the SMR

5. Note that the human capital approach applied here yields exceedingly conservative estimates of the value of life lost. For purposes of comparison, consider that an average of several willingness to pay studies in the United States of America estimates the value of life lost at about US$ 3 million. Taking this USA figure and adjusting for differences in GDP per capita in the USA and Chile (approximately a factor of ten), an estimate of US$ 300 thousand is obtained. If purchasing power parity is used instead (a factor of roughly 3 to 1), the estimated value of a premature Chilean life lost would be about US$ 1 million.

averaged US$1.8 million per year and *the average total cost of typhoid cases attributable to sewage irrigation of vegetables was US$1.4 million per year.*

Table 2.7: Direct Productivity Costs from Typhoid Mortality in the SMR, 1985-1992 (US$)

Year	Total Deaths	Lost Income (US$ '000)
1985	6	224
1986	8	298
1987	9	335
1988	15	559
1989	23	857
1990	20	745
1991	6	224

Note: The annual discount rate used is 5 percent.
Source: Sanchez (1993).

Table 2.8: Total Direct Costs of Typhoid in the SMR, 1985-92 (US$ '000)

Year	Costs of Observed Morbidity (a)	Costs of Imputed Morbidity (b)	Costs of Mortality (c)	Total Costs of Typhoid (b+c)
1985	2,402	1,897	224	2,120
1986	1,571	1,178	298	1,476
1987	638	289	335	624
1988	898	483	559	1,042
1989	1,469	995	857	1,852
1990	795	430	745	1,176
1991	958	679	224	902
1992	174	1	n/a	1
Average, 1985-90	1,296	879	503	1,382

Source: Sanchez (1993); Ferreccio (1993); Ferreccio (personal communication).

Indirect Costs of Health Impacts

2.55 A major concern for Chilean authorities is the potential loss of agricultural exports in the event that a cholera outbreak were to occur in the SMR as a result of the sewage irrigation of vegetables. Agricultural exports for human consumption continue to grow, representing 12-13 percent of total exports in recent years with a dollar value in excess of US$1.1 billion, of which fruit exports account for more than 85 percent. Annual agricultural exports from 1988-92 are shown in Table 2.9. The SMR produces almost 40 percent of the total exportable fruit in Chile.

Table 2.9: Chilean Agriculture, Fruticulture and Cattle Exports
(millions of US$ FOB)

Sector	1988	1989	1990	1991	1992
Agriculture	84.0	124.2	118.1	123.7	150.3
Fruticulture	579.8	549.1	742.7	991.9	981.8
Cattle	39.0	28.9	24.7	21.3	18.3
Subtotal	702.8	702.2	885.5	1,136.9	1,150.4
Total Exports	7,048.7	8,192.3	8,580.3	9,048.4	10,125.5

Source: Sanchez (1993).

2.56 The cost of an eventual restriction is hard to estimate. The history of cholera outbreaks in Israel in 1970 and in Peru in 1991 demonstrates that agricultural export losses can be on the order of many millions of dollars. Chile experienced first-hand the consequences of trade restrictions on its fruit exports by the United States in March 1989, when the USFDA reported that two grapes were found to have traces of cyanide and decreed an embargo on all Chilean fruit. The embargo was quickly copied by other countries importing Chilean fruit. Although the embargo was lifted in stages over a period of several weeks, consumers were subject to a de facto campaign against consumption of Chilean fruit for a longer period.

2.57 The consequences of this episode are hard to quantify. The potential costs go beyond the value of the fruit lost -- whether it was destroyed in the US or removed from the refrigerators and packinghouses in Chile -- to the area of shifting consumer preferences. To estimate the potential loss, it is necessary to predict how long restrictions would be in place, as well as how long the restrictions would bias the choices of consumers. In the case of the "poisoned" grapes, the bias did not last from one season to the next; otherwise, the potential losses due to export reductions could be on the order of hundreds of millions of dollars. In reality, observed fruit export reductions during the 1989 incident appeared to be much lower, on the order of 5 percent of exports, or about US$30 million. There was no apparent effect the following season. Five percent is most likely an underestimate of the losses that year because fruit exports had been growing steadily during the previous years and it was expected to be a very good season for fruit exports. *For this study, the risk of export losses that would result from an eventual cholera epidemic is assumed conservatively to be 5 percent of fruit exports.*

2.58 Other indirect costs are also linked to changes in consumer behavior brought about by the risk of typhoid and cholera. Internationally, tourism to Chile could be affected, especially as the seasonal peaks for these diseases occur during the summer season. At the local level, consumers in the SMR were observed to take special precautions during and following the cholera scare. Such precautions included changing food consumption patterns like foregoing salads or *ceviche*, paying higher prices for vegetables known to be grown in unpolluted areas or irrigated using safe water supplies such as ground water, the use of disinfection solutions or special preparation of vegetables at added costs, or the substitution of other foods at different prices. Not only might these changing patterns result in higher prices to consumers, they could also result in reduced consumer satisfaction. Of all these potential impacts, perhaps the only one easily quantified is the higher prices paid for "safe" vegetables. During the period following the application of crop restrictions in 1991-92, the real prices of the affected vegetables rose between 75 to 100 percent in the SMR (see discussion of agricultural impacts below).

E. Intervention Costs

2.59 The range of policy options and interventions for prevention or reduction of disease transmission linked to water pollution in the SMR were analyzed. An initial screening of potential interventions led to the identification of specific interventions considered by most professionals and authorities to be technically, socially, and politically feasible. The economic costs of implementing each of these interventions were then estimated at the prefeasibility level based on available information. For comparability, all options were analyzed for a period of 30 years using a *financial* discount rate of 10 percent. Wherever possible private sector costs were used. The substudy also examined the complementarities or conflicts between options and provided a qualitative assessment of the effectiveness and effort associated with each of the interventions. The specific interventions considered include:

- full municipal wastewater treatment;
- partial municipal wastewater treatment;
- chlorination of irrigation canals;
- development of alternative clean irrigation water sources;
- restrictions on vegetable cultivation;
- quality certification; and
- public education campaigns.

2.60 Technical studies of policy options and interventions to prevent or control these water pollution problems began in earnest following the period of hyperendemic typhoid from 1976 to 1983. Initial prefeasibility studies on wastewater interception and treatment options were commissioned by EMOS in the mid-1980s, and the first draft master plan appeared in 1987. Based on these initial recommendations, the World Bank-supported project for Santiago Water Supply and Sewerage II (Loan 2651-CH) included financing for construction of two major wastewater interceptors as well as for construction of the Santiago Poniente pilot wastewater treatment plant to test low-cost non-conventional treatment processes at full scale, and for a definitive feasibility study of wastewater treatment options for Greater Santiago. The latter study is currently underway with final results expected in late 1994. This EMOS project has been given new impetus as a result of the cholera outbreak of 1991.

2.61 Similarly, the cholera scare resulted in important new studies commissioned by SAG and DNR on agricultural and irrigation policies and interventions. The initial findings of many of these studies are only recently available and have provided valuable inputs to the present substudy. The background papers and annexed bibliography present the full set of references.

Description of the Problem Area

2.62 Within the SMR, the Greater Santiago urban area generates 90 percent of the municipal wastewater (domestic and industrial) in the region and constitutes the principal source of water pollution. This area includes 34 communes with an estimated total population in 1992 of over 4.7 million. The remaining population lives in scattered rural towns, some of which already have wastewater treatment systems and the rest can be provided by systems independently of Greater Santiago and at minimal cost.

2.63 The wastewater collection system of Greater Santiago is made up of a network with some 6,500 km of sewer mains that evacuate a current average flow of 13 m^3/s. The flow is expected to increase to 25 m^3/s by the year 2024. The wastewater collected is discharged without treatment in more than 40 points[6] along three major natural channels that drain the metropolitan area: the Mapocho River, the Maipo River, and the Zanjon de la Aguada. The effect of these discharges is the pollution of the three natural water courses and, in turn, of the entire network of irrigation canals that derive from them. Bacterial pollution levels in the irrigation canals range from moderately polluted (more than 10^3 fecal coliforms per 100 ml) in most areas irrigated principally by the Maipo River and the upper Mapocho River, to highly polluted (more than 10^5 fecal coliforms per 100 ml) in areas irrigated by the Zanjon de la Aguada and the central and lower Mapocho River. Figure 2.2 shows the rivers and agricultural lands irrigated with contaminated water.

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6. Reduced from some 80 discharge points as a result of the inauguration of the Zanjon Interceptor in November 1993. Also, the Santiago Poniente pilot treatment plant was inaugurated in early 1993 to treat a flow of 0.2 m^3/s.

2.64 The total agricultural area irrigated with the polluted water from the canals in 1990 was on the order of 130,000 hectares. The irrigated areas at risk are distributed as shown in Table 2.10. From the point of view of agriculture, the affected irrigated areas are high-producing agricultural lands that supply the vegetable market of the SMR itself and also produce 40 percent of Chile's fruit exports, and to a lesser extent vegetable exports.

Table 2.10: Irrigation Water Quality and Distribution of Affected Areas

Water Quality	Fecal Coliforms (per 100 ml)	Affected Areas (%)
Safe	$< 10^3$	8
Moderately polluted	10^3-10^4	27
Polluted	10^4-10^5	38
Highly polluted	$> 10^5$	27

Source: SAG (1993).

Wastewater Interception

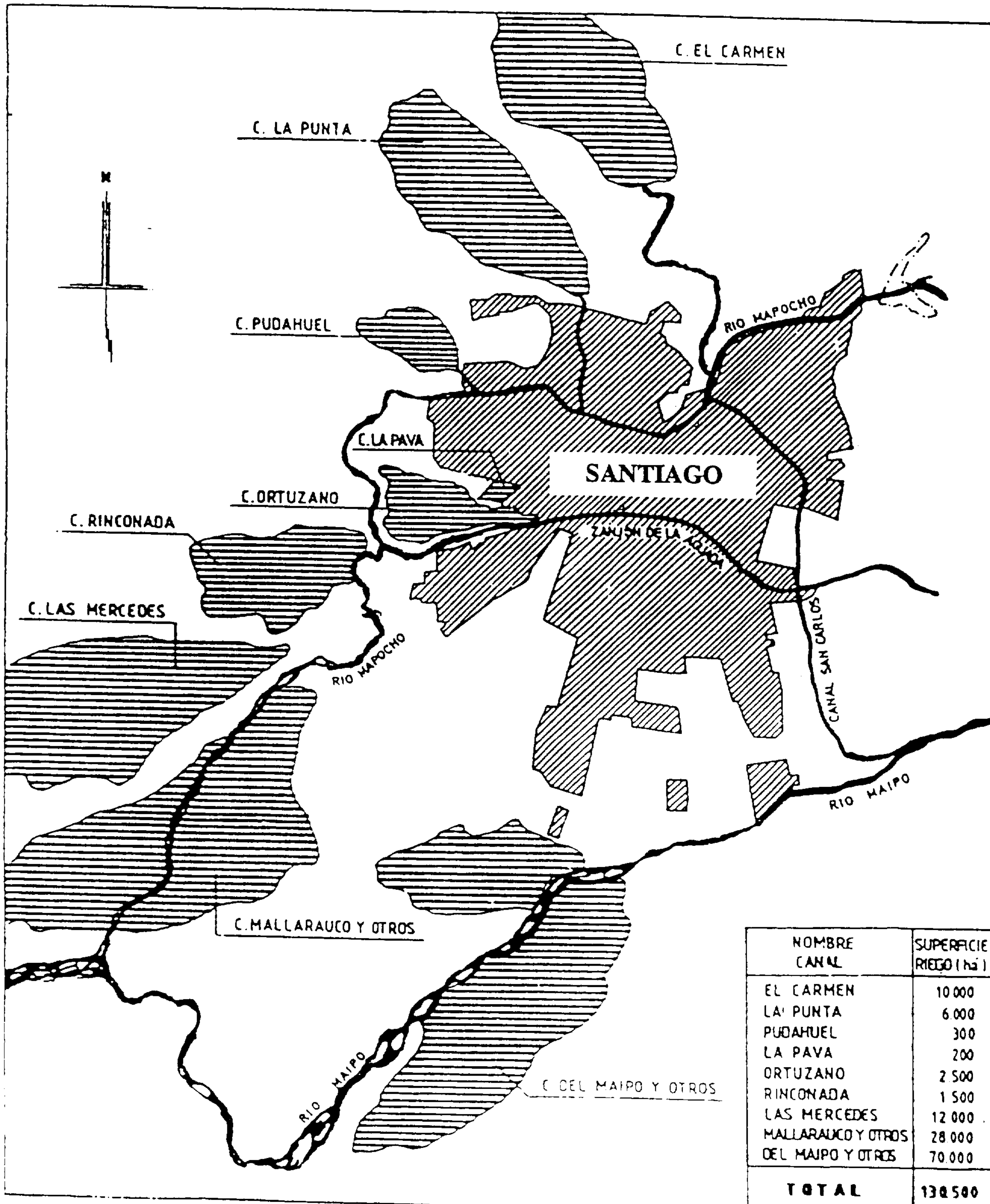
2.65 One important intervention that is not costed in the present substudy is the construction of wastewater interceptors -- since the decision was already taken to proceed with these works. Assessment of future interventions does however require knowledge of the interception plan and its impacts. Interception is important both to sanitize and protect long reaches of presently polluted rivers, making it possible to protect some canals and irrigate the corresponding agricultural areas without problems, as well as to concentrate municipal wastewaters so that they can be treated.

2.66 As a result of construction during 1990-93, some 12,700 ha. of irrigated land are now protected from pollution by Greater Santiago's wastewaters. The completed projects include:

- relocation of the point of discharge of the Tajamar collector to protect the intake of the Canal El Carmen, thus eliminating primary pollution of 10,000 ha of irrigation; and

- completion of the first stage of the Zanjon de la Aguada interceptor, which depollutes the Canal Ortuzano (2,500 ha. of irrigation) and Canal La Pava (200 ha of irrigation); it is important to note that this action results in no dry weather flow, requiring the development of alternative sources of clean water to continue irrigation in these areas.

FIGURE 2.2:
AREAS IRRIGATED WITH CONTAMINATED WATER (1990)



NOMBRE CANAL	SUPERFICIE RIEGO (há)
EL CARMEN	10 000
LA PUNTA	6 000
PUDAHUEL	300
LA PAVA	200
ORTUZANO	2 500
RINCONADA	1 500
LAS MERCEDES	12 000
MALLARAUCO Y OTROS	28 000
DEL MAIPO Y OTROS	70 000
TOTAL	130 500

2.67 Other interception works are either underway or programmed for construction in the near future include:

- the first stage of the Mapocho River interceptor that will enable the depollution of the Canal La Punta, which irrigates 6,000 ha;

- the second stage of the Zanjon de la Aguada interceptor (completion by early 1995), which will result in the protection of 1,500 ha. of irrigation corresponding to the Canal Rinconada and the Canal Loma Blanca; and

- the Maipo River interceptor (to be initiated in 1995), which will, in combination with a wastewater treatment plant of 1.5 m^3/s capacity, eliminate wastewater pollution of the canals of the Asociacion de Canalistas del Rio Maipo, whose total irrigated area is about 70,000 ha.

2.68 When this interception plan is completed, the Greater Santiago wastewater discharges will be concentrated at five points corresponding to the subdrainage areas of the sewer network, as shown in Table 2.11. The wastewater flows can be treated at these points or conveyed to other areas for treatment, reuse or disposal. Note that interception does not resolve the basic problems associated with vegetable irrigation, it simply shifts the problems to downstream areas.

Table 2.11: Greater Santiago Wastewater Flows
by Tributary Zone, 1992 and 2024

Tributary Zone	Flow (lps)	
	1992	2024
Mapocho North	3,750	8,200
Mapocho South	1,170	3,300
Zanjon de la Aguada	8,400	12,400
Santiago Poniente	200	200
Maipo	300	1,500

Source: Katz and Benitez (1993).

Full Wastewater Treatment

2.69 "Full" treatment is understood here as a treatment option that will produce a final effluent in compliance with the Chilean fecal coliform standard for irrigation water (less than 1,000 fecal coliforms per 100 ml).[7] The implication is that treated effluents would be acceptable for unrestricted vegetable irrigation. There are several options for wastewater treatment that can be applied in Santiago, and these may differ for each of the five major discharge points to be considered (Table 2.11). At present, a consulting consortium is completing a study for EMOS on a "Definitive Program of Wastewater Treatment for Greater Santiago." When this work is completed at the end of 1994, detailed cost estimates for the various options will be available. For now, only preliminary cost estimates for full treatment can be made based on consideration of a few options which have already been costed by the consultants.

2.70 The strategy being followed by EMOS is to mobilize private sector financing for the wastewater treatment plants by calling for bids for concession or BOT/BOO-type operations. The commissioned study mentioned above is to provide specifications for the technological alternatives and locations of treatment systems for Greater Santiago, and serve as terms of reference for the bidding process. Bidders will be free to offer any treatment option that produces the required effluent quality at a cost within the range estimated in the aforementioned study.

2.71 The treatment options being studied include several conventional treatment technologies, non-conventional lagoon technologies, and a combination of physical-chemical primary treatment with non-conventional treatment. Up to December 1993, only treatment options for the Maipo zone have been fully analyzed by the consultants. The final design capacity for the year 2024 is 1.5 m^3/s, which only represents 1/16th of the final design capacity for greater Santiago (24 m^3/s). Cost estimates for Maipo treatment options range from US$39 million for non-conventional treatment (anaerobic ponds followed by aerated lagoons), US$46 million for combined physical-chemical primary treatment with non-conventional treatment (facultative ponds followed by maturation ponds), and US$70 million for activated sludge options. These estimates are based on present value of lifetime costs (investment, amortization, operation and maintenance) over 30 years at a 10 percent discount rate assuming similar phased investment programs to go from initial to final design capacity.

2.72 Using information based on Maipo treatment options, and assuming an economy of scale factor of 15 percent, the present analysis extrapolates a total lifetime cost range from US$574 million for non-conventional approaches to US$740 million for half non-conventional and half conventional treatment. As the latter appears more realistic given that sufficient land areas may not be available at all sites to permit the use of non-conventional technologies, it is adopted for the purposes of this analysis. Assuming

7. The Chilean fecal coliform standard for unrestricted irrigation is in line with WHO's guidelines which were recently liberalized (WHO, 1989). The latter are less stringent than the "no risk" irrigation water standards adopted, for example, by the states of Arizona and California.

an average annual sewage flow of 18 m^3/s over the project period, *this is equivalent to US$78 million per year, or about US$0.14 per m^3 (58 pesos per m^3).*

Partial Wastewater Treatment

2.73 The present substudy does not attempt cost estimates for partial treatment options. There are several reasons for this. First, no cost information could be found. Second, the public health authorities (including MOH, SSS and EMOS) are reluctant to accept such options since they do not, by definition, provide full protection for unrestricted irrigation. Criteria and standards to regulate the reuse of partially treated effluents have not yet been developed in Chile nor do there appear to be any on-going efforts in this direction. Finally, partial treatment options are viewed by many as inconsistent with the national objective to protect the image of Chilean agricultural exports abroad. The net result of excluding partial treatment options means that a proper incremental benefit-cost analysis of treatment alternatives cannot be carried out.

2.74 Notwithstanding these concerns, it is feasible to convey wastewater from Greater Santiago to relatively distant valleys, where irrigation systems do not yet exist but which have substantial land areas where combined land treatment and irrigation schemes could be built. There could be serious agricultural interests in support of this solution as well as vested interests in opposition. Partial treatment options to be considered in this case could include natural treatment resulting from in-stream aeration in conveyance canals, use of existing or proposed storage reservoirs as treatment lagoons, and land application in combination with cropping restrictions. A serious analysis of such a scheme is clearly beyond the scope of this report but should be encouraged.

Chlorination of Irrigation Canals

2.75 At the time of the 1991 cholera outbreak, the DNR initiated research to assess the option of sanitation of irrigation canals by disinfection. Results of experiments in three canals in 1992 showed chlorination to be the most cost effective method of disinfection, and also established that only canals of moderate pollution were suitable for chlorination (that is, BOD less than 10 mg/l and fecal coliforms less than 10^4/100 ml). The recommended chlorine dosage was 1.3 mg/l. Further testing was carried out in the Canal El Carmen during the 1993 irrigation season, with an applied dose of 800 kg/day. Fecal coliforms were monitored weekly upstream of the point of chlorination plant and at control points downstream. Monitoring results showed that fecal coliforms were reduced from levels of 10^3/100 ml to less than 10/100 ml for a distance of 16 km downstream, at which point secondary pollution sources raised levels over 10^4/100 ml. Without chlorination, fecal coliform contamination at control points remained above 10^3/100 ml.

2.76 Using the results of these pilot studies, the option of chlorinating all moderately polluted canals was costed. These included six canals in the Maipo system and three in the Mapocho system, with a total flow of about 66 m^3/s. Assuming a chlorine dosage of 1.3 mg/l, the equivalent annual cost of this option over a period of 30 years and discount rate of 10 percent is estimated in Table 2.12. *The estimated present value over 30 years is US$14.9 million, with an equivalent annual cost of US$1.6 million.*

Table 2.12: Estimated Annual Cost
of Chlorination of Irrigation Canals

Item	Annual Cost (US$ '000)
Equipment	34
Operation	331
Chlorine	1,132
Monitoring	60
Total	1,557

Source: Katz and Benitez (1993).

2.77 Note that this option is not an alternative to wastewater treatment, rather it is a measure to protect vegetable irrigation with moderately polluted canal waters. It cannot be used in heavily polluted canals. Also, there are outstanding issues needing further study; for example, questions about the formation of THMs (trihalomethanes) as a result of chlorination, and whether chlorination could be an effective method of protecting against secondary pollution of canals once treatment plants are installed.

Development of Alternative Clean Irrigation Water Sources

2.78 The development of alternative sources of irrigation water can be viewed in two senses. On one hand, farmers may wish to substitute polluted water sources by clean sources such as ground water or impounded clean water. On the other hand, the construction of interceptors and/or treatment plants may deprive some farmers of their current source of irrigation water. The latter case presently occurs in the Zanjon de la Aguada zone, where the construction of the first-stage interceptor discharges downstream of the Canal Ortuzano leaving 2,000 ha without irrigation water. In future, a total of 8,900 ha could be similarly affected, principally in the areas of Ortuzano, Pudahuel, Rinconada, and Las Mercedes.

2.79 The Ortuzano case is used to estimate the costs of developing alternative sources of water. A study commissioned by the DNR (AC Ingenieros Consultores, 1993) identified four possible alternative sources: ground water wells; treated effluents from the Santiago Poniente plant; purchase of water use rights from owners along the Maipo River and reassignment of rights freed up by changes in land use (urbanization); or upstream surface water impoundments for over season storage.

2.80 Due to groundwater limitations, only 800 l/s can be developed from this source, while 4 m^3/s are needed. The construction of 10 wells is proposed for a total investment of US$.59 million. Adding operation (energy) and maintenance costs for 30 years at a discount rate of 10 percent, *the total costs are estimated at a present value of US$ 1.35 million, equivalent US$0.006 per m^3 (2.4 pesos per m^3).*

2.81 The other options have not been costed out, although a very preliminary estimate of the cost of producing treated effluents at the Santiago Poniente plant is on the order of US$0.35 per m^3. As an active market for water use rights has not yet developed in Chile, there are few reliable cost estimates for the option of purchasing or reassigning existing rights.

Restrictions on Vegetable Cultivation

2.82 In 1983, by means of Resolution No. 350, the MOH initiated controls over the irrigation of vegetables commonly eaten raw with polluted water ($> 10^3$ fecal coliforms per 100 ml). This regulation prohibited the cultivation or commercialization of 10 crops: lettuce, chicory, coriander, parsley, radishes (*rabanos, rabanitos*), carrots, berries (*fresas, frutillos, fresones*). Because of the cholera outbreak in 1991, Resolutions No. 3,717 and 10,111 extended the prohibition to five additional crops: celery, cauliflower, beets, spinach, and watercress. The SSA/RM exercises this control by means of periodic inspections.

2.83 The SAG (1993) estimates that 6,970 ha of 12 prohibited crops were being cultivated in the 1990-91 irrigation season in the SMR, equivalent to half the total area in Chile dedicated to these crops. In much of this area, wellwater irrigation infrastructure exists, which farmers claimed to be using. As a result of SSA controls effected in subsequent irrigation seasons, the total area planted with prohibited crops decreased to 4,964 ha in 1992 and 4,924 ha in 1993. According to the SSA, problems in achieving effective control are:

- notwithstanding farmers having wells, groundwater is not used and polluted canal water is applied; and

- to avoid SSA inspections, farmers often irrigate on weekends.

2.84 To estimate the cost of effective implementation of the existing prohibitions, it was assumed that a private round-the-clock inspection system would be put in place built along the line of home watchmen systems. Assuming inspection crews of two persons with vehicle and cellular telephone, the monthly cost was estimated at US$ 4,000 per 5,000 ha. Further assuming that about one-fourth of the irrigated areas is used to grow vegetables, some 30,000 ha would require monitoring over six-month growing season. This yields an annual cost estimate of US$144,000. Thus, over the 30-year period at 10 a percent discount rate, *the present value of enforcing the restrictions would be US$1.4 million.*

Quality Certification

2.85 The SAG, with the support of FAO, is in the process of formulating a program for certification of vegetables according to the quality, nature and security of irrigation water used in the areas where they are grown (SAG, 1993; Fernandez, 1993). Vegetables grown in risk-free areas would receive formal certification from some public agency. A formal certification system would overcome current problems with the marketing of vegetables claimed to originate in risk-free areas, given that there is now no way to detect and denounce fraud in such claims. This option is independent of other interventions and can be implemented simultaneously with each of the others or alone. The results of the SAG study are not yet available and no reliable cost estimate can be made at this time.

Public Education Campaigns

2.86 Public education in a fundamental intervention that is complementary to all of the others and can be implemented independently. The importance of public education in the control of typhoid in the SMR has been demonstrated by Ferreccio (1993). Public education campaign costs depend on many factors, including the target audience, the means of communication used, and the frequency and duration of the campaign.

2.87 To estimate the economic costs of a public education campaign, information was obtained from private public relations firms. It is assumed that an effective public health campaign, which requires the use of mass media, should include as a minimum:

- television coverage during peak viewer hours, about four times a day;
- posters and brochures in public places such as the metro, buses, health clinics, schools and elsewhere; and
- articles and advertisements in newspapers and magazines.

2.88 The cost of a two-month campaign of this kind in Chile is about US$ 500,000. Assuming three campaigns a year (US$1.5 million per year) for a period of 30 years and a discount rate of 10 percent, gives an *estimated present value of US$14 million*.

F. Impacts on Farm Profitability

2.89 The set of possible interventions to control the health impacts of water pollution in the SMR were also examined from the point of view of their possible effects on agriculture in the region. The main potential impacts on farm-level profitability of each intervention option are as follows:

(a) Full municipal wastewater treatment. The interception and treatment of wastewater will have three major impacts. First, irrigation water flows will be reduced in some areas where farmers would lose production or would have to invest in alternative water sources or more efficient irrigation systems. Second, the fertilizer value of the organic material in wastewater (high in nitrogen and phosphorus) will be significantly reduced by treatment and fully lost in areas deprived of wastewater by interception. Third, it will be possible to grow prohibited vegetables in areas currently controlled resulting, in increased farm income.

(b) Partial municipal wastewater treatment. In the event that the wastewater of Greater Santiago were intercepted and conveyed to new irrigation areas, irrigation in the SMR would be reduced by as much as 24,000 ha. New farmers would benefit, but present farmers would lose production or would have to invest in alternative water sources or more efficient irrigation systems.

(c) Chlorination of irrigation canals. This option would only affect farmers if the costs were passed on to them. Farmers claim to have a right to clean water and are reluctant to participate in financing this program. If the consumer concern about potential THM formation were to arise, irrigated produce prices could drop.

(d) Development of alternative clean irrigation water sources. Farmers in irrigation areas served by polluted canals and wishing to produce safe vegetables would have to invest in developing alternative clean sources, as would those losing access to wastewater flows. The corresponding investment and operation costs would, in some proportion, have to be incorporated in their production costs. In the case of ground water sources in Ortuzano, although the bacterial quality of the ground water source is excellent, there are chemical quality limitations associated with their prolonged use. In general, when substituting Mapocho River waters with Maipo River waters or ground water sources, some sensitive crops may be affected, like berries, carrots, avocado, onions, and pimento.

(e) Restrictions on vegetable cultivation. The consequence of crop restrictions is a change in the cropping structure of affected areas with corresponding changes in farm income. This impact is deemed to have occurred already; it remains to be seen whether or not the change is permanent.

(f) Quality certification. The impact on agricultural profitability of a produce quality certification program would be reflected in the price of the benefited crops. A second impact would be the cost of the program if it is passed on to producers.

(g) Public education campaigns. The impacts of public education will be reflected in produce prices; prices could increase if the campaign is oriented toward promoting vegetables originating in safe areas or certain crops unaffected by pollution, or decrease if the campaign warns against the consumption of vegetable crops susceptible to contamination.

2.90 In an attempt to give a value to some of these impacts, the analysis focuses on the following aspects: the agricultural cost of wastewater treatment; the opportunity cost of untreated wastewater; willingness to pay for alternative irrigation water sources; and the observed impacts of the crop restrictions imposed in response to the 1991 cholera outbreak.

Agricultural Cost of Wastewater Treatment

2.91 The impact of wastewater interception and treatment on farm-level profitability is considered as equivalent to the present value of the change in adjusted net income of irrigated agriculture in the area of influence of the project. The adjusted net income corresponds to the value of production less the direct costs of production adjusted, as needed, for indirect costs associated with irrigation. The change in net income is due to the three impacts described above: reduction in irrigated area; loss of fertilizer value of wastewater; and return to cultivating crops previously prohibited. These impacts do not occur uniformly in all affected areas, but for analytical purposes they are separable and can be quantified separately and in combination.

2.92 A model has been developed by Brzovic (1993) using available data on wastewater quality and flows, irrigated areas, and cropping patterns to compute the cumulative effect of these three types of impacts on the present value of adjusted net income in the areas irrigated by waters from the Maipo River, the Mapocho River, and the Zanjon de la Aguada. For a period of 30 years and a discount rate of 10 percent, and assuming constant prices, the model produces the following estimates of the present value of impacts as shown in Table 2.13.

Table 2.13: Effects of Wastewater Interception and Treatment on Farm Level Profitability

Effect	Present Value (US$M)	Annual Value	
		(US$M/yr)	(US$/ha)
Impact 1: reduction in irrigated area	-40.0	-4.3	-54
Impact 2: loss of fertilizer value of wastewater	-5.5	-0.6	-8
Impact 3: return to cultivating prohibited crops	60.3	6.4	78
Combined impact	14.4	1.5	16

Source: Brzovic (1993).

2.93 This is equivalent to about US$1.5 million per year in net benefits for the entire area. Benefits are not distributed uniformly, however, with a larger share of benefits corresponding to areas irrigated from the Maipo River. A sensitivity analysis varying the values of key parameters by 30 percent in either direction causes the overall net benefits to range from losses of US$1.5 million per year up to gains of US$3.5 million per year.

Opportunity Cost of Untreated Wastewater

2.94 The opportunity cost in this case can be interpreted as the sacrifice made by the agricultural producer, or society, when voluntarily deciding to give up a polluted irrigation water source. The opportunity cost to the farmer is zero if the wastewater cannot be used anyway because of legal restrictions. There is a cost to society, however, when the decision to restrict wastewater reuse is made. With or without water quality standards, there may be a real economic loss; so the question is whether or not it is inevitable.

2.95 The opportunity cost of abandoning a polluted source includes the three economic impacts described in the previous section and estimated in Table 2.13. From the model estimates for the study area, this component of the opportunity cost would be the sum of the losses associated with reduced fertilizer value and irrigable area (approximately US$62 per ha per year for the 30-year period of study) and the benefit derived from growing higher-value vegetables (about US$78 per ha per year). In net terms, there would be on average an "opportunity benefit" of US$16 per ha per year according to the model.

2.96 However, the opportunity cost of opting for a clean source of irrigation water, including treated wastewater, would be the opportunity cost of lost fertilizer value plus the costs of investment and operation of works associated with the new source, conveyance costs for treated wastewater, as well as any tariff that might be charged for treated effluent reuse.[8] As examples, the total investment costs for constructing and rehabilitating 10 wells in the Ortuzano area is on the order of US$900 to 1,100 per ha and outside the SMR recent construction projects have cost US$770 to 1,080 per ha for the Victoria-Traiguen irrigation canal, and US$2,500 to 3,210 per ha for the Puclaro reservoir. When imputing costs for investments in irrigation works, it is important to include any subsidies to producers.

Willingness to Pay (WTP) for Alternative Sources

2.97 Farmers should be willing to pay for alternative sources of clean irrigation water up to the equivalent of the net marginal benefits that the new source makes possible. The net marginal benefits may derive from several sources: increased area under irrigation, increased flow or regularity of irrigation water, replacement of a prohibited wastewater source, or because a clean source allows growing crops with higher prices.

2.98 One measure of WTP is the price farmers would pay for water use rights, assuming that a developed market exists for transacting water use rights. In Chile, such a market is not yet fully developed; water use rights are assigned *gratis*, and farmers rarely engage in buying, selling or leasing rights -- most likely leading to low WTP. One reported example of an irrigation transaction is for the Recoleta-Paloma-Cogoti system, where farmers have paid on average 40 pesos per m^3 for irrigation water, or about US$0.10 per m^3, which is a representative value worldwide. A few transactions have been recorded in the SMR over the past few years for municipal and industrial water supply. These have involved water shares in the upper Maipo, which have traded at values between 5.7 and 7.6 million pesos per share. Current value per share is estimated at 8 million pesos; this is equivalent to 64 pesos per m^3 (US$0.16 per m^3) since each share represents 3.8 lps (Aninat et al., 1993).

2.99 Another measure where a developed agricultural land market exists is the difference between land prices for irrigated land versus dry land with the same potential for economic production, assuming the costs of irrigation investments are incorporated in land prices. This is not always the case, as beneficiaries of irrigation works are often

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8. It is uncertain that EMOS would charge users for treated effluents since to do so would legally require a proportional reduction in water and sewerage charges; that is, there would be no benefit to EMOS, but most likely substantial administrative complications.

subsidized up to 75 percent of investment costs and 50 percent of total cost (primarily for small works).

2.100 Evidence of farmer WTP for irrigation water is provided by recent surveys (Aninat et al., 1993). A WTP survey for the Puclaro reservoir estimated that beneficiaries are willing to pay up to US$160 per ha for irrigation water (roughly 3 pesos per m^3), while the estimated real costs are US$420 per ha. Similarly, for the Victoria-Traiguen irrigation canal, farmer WTP was estimated at US$70 per ha. (about 1 peso per m^3), while true cost is about US$125 per ha. This is consistent with other evidence in the SMR that farmers are only willing to pay about one peso per m^3 for irrigation water. In these examples, WTP is roughly enough to cover the operational costs of irrigation but not investment costs.

Observed Impacts of 1991 Crop Restrictions

2.101 Although successive public health restrictions on growing vegetable crops irrigated with wastewater have been in place since 1941, they were never effectively enforced due to lack of resources and political will. Only in 1991, as a result of the cholera outbreak, were serious actions taken to force compliance, with prior and new regulations placing restrictions on a total of 15 different crops. Actions included intensified sanitary inspections of irrigated areas and water quality monitoring in the SMR, and even the destruction 130 ha. of prohibited crops, resulting in a drastic reduction in supply. This was accompanied by a public health information campaign aimed at influencing demand for and raw consumption of prohibited crops.

2.102 Several important impacts were observed in the horticulture industry, mostly due to the actions taken:

(a) Adjustments in supply and demand: Intensified SSA inspections and enforcement actions in the SMR resulted in an overall reduction in 1992 of over 2,000 ha (-29%) in irrigated area dedicated to the cultivation of 12 prohibited crops. This impact was maintained in 1993 as well. Among the most significant reductions in area were those corresponding to: lettuce (-26%), carrots (-17%), spinach (-29%), and parsley (-53%). Also, the corresponding volumes traded in wholesaler markets in Santiago dropped in the first year by 43% on average, including celery (-50%), cabbage (-48%), carrots (-42%) and lettuce (-33%), which are particularly important because of their total value. In the second year of restrictions, however, a recovery to previous levels in volumes traded was observed -- explained in part by public reaction to the fact that the cholera outbreak was controlled, and changes in marketing channels including the increased sale of produce originating outside of the SMR. As a result of the contraction in supply in 1991, real prices for the prohibited crops rose between 25 and 50% on average. More striking than the price increases in the first year of restrictions is the continuing tendency toward higher prices in the second year; real prices for the 12 crops rose between 75% and 100% on average. This has been attributed to higher production costs for these crops, and real prices are likely to remain well above pre-cholera levels in the future. Increased consumer costs are estimated in Table 2.14 using SMR data on wholesaler prices and volumes sold in wholesaler markets for four of the most important prohibited crops (celery, lettuce, cabbage, and carrots). Together these four crops account for 88 percent of the total land planted with prohibited vegetable crops. Estimates of increased consumer costs for these vegetables following the cholera crisis are on the order of US$6.4 million in 1992, and US$5.5 million up to August 1993. *Extrapolating to the total area, the estimated annual consumer cost increase is US$7.2 million.*

(b) Relocation of horticulture zones: As a result of the restrictions placed by the SSA on vegetable cultivation in the SMR, a geographical shift in crops has occurred both within the region and well as between regions. The interregional shift has been toward Regions IV and VI; for example, in Regions IV the areas dedicated to growing lettuce, cabbage, and carrots have doubled or tripled. Nationally, however, the largest volumes still continue to be produced in the SMR. Within the SMR, shifts in cultivation are not well documented. According to SAG, a reduction of almost 900 ha. of vegetable cultivation occurred in the most heavily polluted areas, while some 200 ha have been added in areas where deep wells exist and irrigation canals have been chlorinated by DNR. Where prohibited crops have been reduced, they are often replaced by tomatoes, potatoes, or wheat. Several costs are associated with crop shifts. First, there are short-term costs of learning and adjustment related to new crops. Second, a likely reduction in profitability per hectare occurs as "second best" crops are grown. Third, production costs rise as a result of factors like use of well water, increased distances from markets, and new requirements such as packaging, identification of place of origin, and more specialized marketing networks. Finally, labor demand drops when crop shifts are from highly labor intensive vegetables to less labor intensive alternatives. Studies would be needed to quantify these impacts of the cholera outbreak.

(c) Effects on the horticulture industry: A positive impact of the cholera scare has been the induced modernization of the horticulture industry. More stringent consumer preferences are reflected in improvements in the quality and presentation of produce, which in turn requires more specialized marketing networks and wholesalers. Packaging which purports to identify the point of origin and quality of the product is now commonplace. Although there is the real likelihood of fraud or misrepresentation, it is a first step toward increased consumer discrimination and price differentiation. All indications are that these practices will become formalized in the future. Another effect appears to be an increase in average plot size and more use of technology in both irrigation and cultivation systems possibly resulting from the increased prices for restricted crops.

Table 2.14: Values of Restricted Vegetables Sold Annually in the SMR, 1985-1993 ($, pesos of August 1993)

Year/Item	Restricted Vegetables				Total Value (M$)
	Celery (dozens)	Lettuce (1,000 no.)	Cabbage (100 no.)	Carrots (1,000 no.)	
Ave. 1985-90:					
Volume (units)	575,306	46,231	100,434	123,878	
Price ($ per unit)	1,002	2,737	8,223	7,410	
Value (M$)	577	127	826	918	2,478
1991:					
Volume (units)	275,290	30,284	52,190	72,357	
Price ($ per unit)	952	3,677	10,569	8,683	
Value (M$)	262	111	552	628	1,553
1992:					
Volume (units)	480,436	54,412	99,315	96,946	
Price ($ per unit)	2,049	5,373	14,752	8,798	
Value (M$)	985	292	1,465	853	3,595
To August, 1993:					
Volume (units)	698,981	39,681	79,094	145,875	
Price ($ per unit)	1,751	6,248	12,002	8,276	
Value (M$)	1,224	248	949	1,207	3,628

Source: Brzovic (1993).

2.103 A detailed cartographic study commissioned by the DNR (IPREN, 1993) was carried out to analyze the impacts on local land use in two areas near Greater Santiago irrigated by the Canal Ortuzano and the Derivado El Carmen, totaling 6,913 ha. The first conclusion is that the recent shifts in the structure of land use are not due solely to the emergency measures undertaken in 1991 to combat cholera. In addition, land use is changing as a result of the conversion of horticultural land to more profitable fruit orchards, as well as the growth of Greater Santiago. The expansion of areas planted in permanent crops (fruit trees and grape vines) is more than 1,200 ha. On the other hand, 1,700 ha. (mostly in Ortuzano) have been converted to urban land use on the outskirts of the city. With regard to vegetable crops, a significant shift of prohibited crops has been observed from the area of Canal Ortuzano, which decreased by more than half, to the area of Derivado del Carmen, which almost tripled.

2.104 A farmer survey was also carried out to determine the motives for land use changes observed between 1989 and 1993. The reasons given are illuminating: *57% of the cases were the result of restrictions placed on crops by SSA*, 33% were due to converting land to more profitable fruit production, and 10% were the result of urbanization. The influence of these other factors, in addition to the cholera prevention measures, makes it difficult to quantify the direct agricultural cost of crop restrictions.

G. Regulatory and Institutional Framework for Water Quality Management

2.105 Progressive changes in the water resources sector have been underway in Chile since the reform of the Water Code in 1981, including major regulatory and institutional reforms. Water quality management, however, has not yet figured prominently among the changes. The regulatory and institutional framework embodied in the Water Code, with emphasis on private water use rights, market logic and subordination of the State, ignores fundamental linkages between water *quality* and *quantity*, which derive both from the natural laws of hydrology and from competing economic uses. Proposed modifications to the Water Code presently being considered by parliament may help create a more appropriate framework for managing water quality problems through the creation of river basin corporations and redefinition of the rights and responsibilities of water users -- including dischargers.

2.106 Pressure to give greater attention to water quality issues may also result from environmental reforms. The Basic Law on the Environment was recently approved and seeks to give definition to the constitutional principle that each citizen has the right to live in an environment "free of contamination." This is interpreted as an environment in which water quality standards, among others, are met. Regional environmental commissions supported by CONAMA are to be responsible for enforcing the law. International environmental pressure will increase as Chile seeks to participate in free trade agreements; for example, the private sector will have to give serious attention to international trade requirements such as the ISO 9000 quality certification standard and the emerging ISO 14000 environmental auditing standard.

Regulatory Issues

2.107 The problem of irrigation-related typhoid in the SMR has been under discussion for three or four decades, and there is a long history of legislation on the subject. In 1941, the Direccion General de Sanidad in Resolution No. 1,138 restricted the planting of vegetables in areas irrigated with sewage. Article 71 of the 1967 Sanitary Code explicitly prohibits the use of water contaminated by sewage for the irrigation of food crops that grow close to the ground or are eaten uncooked. The revised water code of 1981 charged the municipalities with direct responsibility for implementing laws on water quality, and gave the DGA wide powers to apply the law and coordinate the various agencies whose mandates touched on water quality. In the absence of any action, and in response to hyperendemic typhoid conditions, the prohibition was reiterated in 1983 in Resolution No. 350 of the Ministry of Health, and amplified in Resolutions No. 3,717 and No. 10,111 in 1991. Also, SAG Resolution No. 576 prohibited the transport of restricted vegetables and fruits outside of the SMR if they are irrigated with sewage. Finally, national water quality standards for irrigation were promulgated in Norma Chilena No. 1,333 (1978), including a fecal coliform standard of 1,000 MPN/100ml in accordance with WHO recommended guidelines, as well as standards for trace metals and other parameters. The effectiveness of the standards and the most recent resolutions is still in doubt.

2.108 Notwithstanding national concern about bacterial pollution in the SMR and the promulgation of diverse regulations and standards, little progress in enforcement was achieved until the 1991 cholera crisis. This illustrates the importance of political will in the face of entrenched water user interests. In addition, the fragmentation of responsibility for enforcing existing regulations is a contributory factor. For example, MOH, SAG, DNR, DGA all have some responsibility for enforcing Chilean Standard 1,333 and a coordinated approach has not been achieved. Simple agreements are necessary on questions like where do standards apply, and where and how to monitor.

2.109 Regarding industrial wastewaters, the first laws were promulgated in 1916 (which remained without corresponding regulation until the Decreto Supremo No. 351 issued in 1993!). Only with the creation of the SSS in 1990, however, has serious attention been given to the problem of industrial discharges into municipal sewer systems. The SSS has made progress on an industrial discharge inventory for the SMR and the formulation of pretreatment and discharge standards. It is still not clear, however, as to what policy instruments are needed and how the eventual standards will be applied. Industrial discharges are likely to limit wastewater reuse and cause other water pollution problems in the future unless effective control policies are promulgated by SSS and implemented by EMOS and the industrial sector.

Water Use Rights Issues

2.110 The system of allocating water use rights in Chile has many shortcomings from a water quality point of view. In the 1981 Water Code, only in the case of non-consumptive water use rights is there an obligation to respect the quality requirements of downstream rights holders. The constitutional right to an environment free of contamination can also be viewed as a form of property right, but it is not yet codified in a way that permits comparison to water use rights -- a limitation to taking legal action through the courts for pollution abatement. Such environmental property rights can be defined, among other ways, by regulation (for example, setting discharge standards that must be met) or by economic instruments (for example, effluent charges), or a combination of both.

2.111 Although water use rights are property rights that can be bought and sold, they are allocated *gratis*[9] by the state and are not taxed. Neither extraction taxes nor effluent taxes are currently used by the government as a means of imputing a use value or an environmental value to water resources nor to raise revenues for environmental actions. Notwithstanding the great effort made to develop a water market, transactions are rare, a large amount of water rights are held for speculative purposes, and the lack of depth of the water market undermines potential transactions for reclaimed wastewater.

Intersectoral Issues

2.112 Each of the water-using sectors in Chile has evolved a legal and institutional framework that is both technically and economically advanced and consistent with the prevailing economic model in Chile. However, the framework for managing relations between water uses and users at the basin level is inadequate, especially with regard to environmental interactions. New mechanisms and institutions are needed to help resolve water quality conflicts, either through negotiation or litigation.

2.113 A major initiative in this direction are recent efforts to create some form of river basin institution that would enable participation of both public and private interests in decisions on water management and also provide a forum for negotiation. The World Bank is supporting a pilot project in the Bio-Bio basin that would permit the DGA to create and test the concept of a river basin corporation.

2.114 With reference to water pollution control, the coordination of regulatory functions across sector agencies is a critical issue. There are many institutions involved in managing water quality, in many cases with overlapping responsibilities and inadequate mechanisms of coordination, as reflected in water pollution levels observed despite the attention given to this issue.

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9. The DGA charges only a modest administrative fee unrelated to the value of the water use right.

H. Policy Implications

2.115 Combining the results of the five substudies leads to a better understanding of a number of policy issues concerning environmental health protection and water pollution control in the SMR. Among the issues to be examined in this section are the following:

(a) the costs and benefits associated with major environmental health policy decisions made or being considered, specifically with regard to four distinct periods: the period of hyperendemic typhoid (1976-1984), the period of endemic typhoid (1985-1990), the cholera emergency period (1991-1993), and the period of investment in wastewater treatment in the SMR;

(b) the emerging environmental health priority for wastewater treatment and reuse in the SMR -- the control of industrial discharges; and

(c) the role of integrated water quality management in the evolving regulatory and institutional framework for water resources planning and management in Chile, and its implications for the Maipo-Mapocho Basin.

A Policy Cost-Benefit Analysis

2.116 A policy cost-benefit analysis of recent or pending decisions is attempted here based on the information resulting from the substudies. The purpose of a policy CBA is to identify costs to society which possibly could be averted or reduced if a policy change were implemented or a program initiated. The focus is on environmental health policies, both past and future, to control the impacts of vegetable irrigation with polluted waters in the SMR. Three policy scenarios are examined: (a) the transition from hyperendemic to endemic typhoid; (b) the cholera emergency; and (c) the option of full wastewater treatment. Order of magnitude estimates are made of the costs and benefits with and without the major policy decisions (historical or pending) associated with each scenario. The estimates help shed light on the reasonableness of the decisions.

2.117 Scenario 1: Controlling Hyperendemic Typhoid. During the period 1976-84, rates of typhoid and paratyphoid morbidity in the SMR averaged on the order of 150 cases per 100,000 population. This rate was cut by two-thirds to about 50 cases per 100,000 between 1983 and 1985 principally as a result of two limited interventions: in 1984 the public health authorities prohibited the cultivation of vegetable crops consumed raw (MOH Resolution No. 350), and they initiated a public education campaign on the risks of sewage irrigation for health. Another important decision taken by EMOS was to initiate feasibility studies on wastewater interception and treatment, although this measure had no immediate water pollution control impact. Strict enforcement of

Resolution No. 350, however, was not pursued and endemic typhoid persisted in the SMR until the cholera outbreak in April 1991.

2.118 In retrospect, there was insufficient political will to do more than try to raise public awareness and lay the groundwork for possible future decisions. Implicitly, policy-makers were indicating that the costs of control were viewed to be much greater than the perceived health benefits. While there is not much information available from the period, rough estimates of costs and benefits can be made using current information. These estimates support the conclusion that policy-makers were acting rationally.

2.119 Without any interventions, the continued health impacts of hyperendemic typhoid would have been on the order of US$4.2 million per year (three times the value of attributable morbidity and mortality during the endemic years of 1985-90 [para. 2.54]). The health benefits derived from the limited interventions taken can be estimated as two-thirds this value, or US$2.8 million per year. The approximate private sector costs of these interventions, if fully implemented, would have been about US$1.6 million per year -- the cost of public education campaigns (US$1.5 million per year [para. 2.88]) plus the cost of inspections (US$144,000 per year [para. 2.84]). As shown in Table 2.15, the net benefit would be approximately US$1.2 million per year, *indicating that these limited interventions were justified.*

Table 2.15: Policy Cost-Benefit Analysis Summary for Scenario 1 (partial measures taken in response to hyperendemic typhoid, 1984)

Annual Benefits	US$M	Annual Costs	US$M
Reductions in typhoid mortality and morbidity	2.8	Public education campaigns Inspection program	1.5 0.1
Total annual benefits	2.8	Total annual costs	1.6
B-C	1.2		

2.120 A decision to take more drastic action, such as the emergency measures of 1991, when sewage irrigated crops were destroyed and effective enforcement achieved, would have had additional political costs. Assuming responses similar to those observed during 1991-93, conservative estimates of the added costs would include farm income losses of US$4.9 million per year due to restrictions in irrigated area and loss of fertilizer value of water (Table 2.13), and US$7.2 million per year in increased consumer costs (para. 2.102.a). Loss of Chilean agricultural exports did not appear to be a major consideration at the time. Against these costs, additional health benefits from typhoid reductions to present levels would only have been US$1.4 million per year. *The political* *choice to delay action and undertake needed studies of intervention options appears to have been reasonable.*

2.121 Scenario 2: The Cholera Emergency: The situation changed dramatically in April 1991, with the outbreak of cholera in the SMR and elsewhere in Chile. The spread of cholera by the long cycle is well known, and it could be expected that without immediate action cholera would become an epidemic disease in an unprotected population, greatly surpassing typhoid in importance. Judging by the outbreak in neighboring Peru, the expected consequences would include major health impacts and loss of exports. Emergency measures were quickly put in place that included the prohibition of growing vegetables using sewage irrigation, the prohibition of serving raw vegetables, and an intensive campaign of social communication informing the population of the risks of vegetables and the need to wash and cook them. New public health resolutions were passed and enforced; field inspections were carried out in areas irrigated with polluted water and prohibited vegetables found growing there were bulldozed and burned. The results of these emergency actions were dramatic. The cholera outbreak was stopped before it reached major proportions. In addition, for the first time since obligatory registration was initiated in 1950, endemic typhoid in the SMR was brought under control.

2.122 Without the emergency measures the health impacts could have been significant. The spread of cholera in a previously unexposed population without antibody protection and inadequate sanitation and food hygiene is exemplified by Peru, where in 1991 there were some 1,500 cases and 13 deaths per 100,000 population. The direct and indirect health costs of the 1991 cholera outbreak in Peru are estimated at US$91.9 million (WASH, 1993). The cholera rates in Peru have been reduced to about 300 cases and 2 deaths per 100,000 in 1993, but are likely to remain at endemic levels for years to come. Looking at typhoid, another disease transmitted by the long cycle and common to both countries, gives an indication of the risk of cholera transmission in Chile. The average rates for typhoid are 75 cases per 100,000 in Peru, very similar to historical typhoid rates observed in the SMR (50-150 per 100,000). Clearly, the risk of a major cholera epidemic existed in Chile.

2.123 While it is contentious to extrapolate the Peruvian cholera outbreak results to Chile (because of significant differences in levels of income, education and environmental hygiene, the greater role of the short cycle in transmitting cholera and typhoid Peru), the fact that typhoid levels in Peru were comparable to those in the SMR prior to the cholera outbreak justifies the comparison to provide at least an upper bound to the potential health costs. Assuming a similar proportion of cholera to typhoid cases as was observed in Peru, the SMR could have expected some 20 times the number of imputed typhoid cases. Thus, some 32,520 annual cases of cholera due to vegetable irrigation could be expected based on an average of 1,626 imputed cases of typhoid annually during the period 1985-91 (Table 2.2). Further assuming a cost structure for health care and productivity losses based on cholera case parameters observed in Peru coupled with Chilean unit costs, the economic impact of an uncontrolled cholera outbreak could have reached US$14.7 million in 1991.[10] Even if only rough estimates, it is clear that the health, social, political, and economic risks of cholera were great and clearly demanded action.

2.124 The second major risk of inaction involved agricultural exports. The recent history of the 1989 "poisoned grape" episode provides an initial estimate of this risk of about 5 percent of fruit exports (para. 2.57), equivalent to about US$50 million in 1991.

Table 2.16: Policy Cost-Benefit Analysis Summary for Scenario 2
(emergency measures taken against cholera outbreak, 1991)

Annual Benefits	US$M	Annual Costs	US$M
Reductions in typhoid mortality and morbidity	1.4	Public education campaigns	1.5
		Inspection program	0.1
Avoided cholera mortality and morbidity	14.7	Farmer losses	4.9
Avoided export losses	50.0	Consumer losses	7.2
Total annual benefits	66.1	Total annual costs	13.7
B-C	52.4		

2.125 The emergency measures taken in 1991 resulted in reducing the health costs of typhoid by US$1.4 million per year (para. 2.54) and in avoiding the risks identified above. Summing these potential losses gives the total annual expected health and related benefits, which are on the order of US$66.1 million (Table 2.16). The corresponding costs were not, however, insignificant. On an annual basis these costs included intervention costs on the order of US$1.6 million, losses to farmers of about

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10. As reported by WASH (1993), the 1991 outbreak in Peru resulted in 62 percent of cholera cases requiring ambulatory care with an average of one disability day, 34 percent requiring hospitalization with 4 disability days, and 4 percent hospitalized with complications and averaging 7 disability days. Of all cases, 0.9 percent of cases ended in death. The average cost of medical treatment in Peru was US$94 per case. A work day lost in the SMR represents a productivity loss of US$9.50 (285÷30 from Table 2.4), and each death represents a weighted average lost income equal to US$37,255 (para. 2.53). Applying these parameters to the number of expected cholera cases in the SMR yields estimates of: (a) US$3.1 million for medical treatment; (b) 73,495 disability days valued at US$0.7 million in productivity losses; and (c) 293 deaths valued at US$10.9 million in human capital losses.

US$4.9 million, and increased consumer costs of about US$7.2 million. The total annual costs are thus about US$13.7 million. Compared to the risks of inaction, these costs appear acceptable, and *the decision to implement the emergency measures seems reasonable.*

2.126 Notwithstanding the apparent success of the actions taken in controlling cholera and typhoid, and to a lesser extent hepatitis, there is still concern among public health authorities and others about the sustainability of these emergency measures. By their nature they depend on maintaining the cooperation of farmers and the public, as well as the political will to continue effective monitoring and enforcement. There are already signs of laxity in inspections and public vigilance. The only measure robust enough to guarantee full and lasting public health protection is that of wastewater interception and treatment. In recognition of this, a master plan for interception and treatment of Greater Santiago's wastewater was already under development in the mid-1980s. Even before the cholera outbreak the decision was already taken to make initial major investments in wastewater interception in the most heavily polluted areas and in 1990 work on the priority interceptors had begun. The remaining policy question is to what extent is investment in full wastewater treatment justified on the basis of public health considerations in the SMR. This question is examined in the final scenario.

2.127 Scenario 3: Full Wastewater Treatment. The cost of the full treatment option has already been estimated at US$78 million per year, or roughly US$0.14 per m^3 equivalent cost (para. 2.72). Investments in interception are considered sunk costs for the purpose of this analysis, as the decisions are already taken and construction is underway. This also implies that losses to farmers (reduced irrigated area and fertilizer value of wastewater) in the areas affected by interception should also be considered sunk costs. Even with treatment, agricultural inspection programs and public education campaigns should continue so that there are no associated incremental costs or benefits.

2.128 The introduction of full wastewater treatment would guarantee perpetuation of the benefits associated with eliminating endemic typhoid and avoiding the spread of cholera that were identified above in scenario 2 (para. 2.123-2.125). Initially it may be incorrect to fully ascribe these benefits to the treatment intervention since they have already been achieved through the emergency measures. In the long term, however, only treatment will ensure their sustainability. Accepting this argument, the health and trade related benefits would be around US$66.1 million per year. A more conservative estimate of risk would be to assume that the emergency measures would fail one year in five, so that 20 percent of the overall health and trade-related benefits are attributed to this intervention, equivalent to about US$13.2 million per year.

2.129 In addition, benefits resulting from wastewater treatment and reuse would accrue to farmers in areas downstream of interceptor discharges, since they would be able to cultivate vegetable crops without restriction and return to former (pre-1991) levels of income assuming constant prices. This effect is valued at US$6.4 million per year (Table 2.13). There would also be benefits to consumers in the form of a rollback in price increases for prohibited crops. This effect could be as much as 57 percent of US$ 7.2 million per year (para. 2.102.a and 2.104), or about US$4.1 million per year. These associated benefits total about US$10.5 million per year. Table 2.17 summarizes the annual costs and benefits associated with the full treatment option.

2.130 The total annual health and associated benefits corresponding to wastewater treatment and reuse in the SMR would, in this scenario, be in the range of US$24 million assuming a one-in-five year risk, up to in excess of US$77 million assuming full risk. *The conclusion is that these benefits offset a significant share (one-third to almost all) of the cost of wastewater treatment.*

Table 2.17: Policy Cost-Benefit Analysis Summary for Scenario 3 (investment in full wastewater treatment)

Annual Benefits	US$M	Annual Costs	US$M
Reductions in typhoid mortality and morbidity*	0.3-1.4	Wastewater treatment	78.0
Avoided cholera mortality and morbidity*	2.9-14.7		
Avoided export losses*	10.0-50.0		
Expanded farm output	6.4		
Reduced consumer costs	4.1		
Total annual benefits*	23.7-76.6	Total annual costs	78.0
B-C*	(54.3)-(1.4)		

* A range of benefit estimates is given reflecting different risk assumptions about the failure of the emergency measures currently in place; the first estimate assumes a risk of failure one year in five, while the second estimate assumes full risk every year.

2.131 This study looks exclusively at the health impacts of typhoid and cholera, both diseases considered to be propagated primarily by the long cycle of transmission. It does not attempt to assess the costs of hepatitis (which are also considerable but not predominantly linked to the long cycle of transmission), nor of other gastroenteric diseases such as diarrheas and parasitosis.[11] Nor has it attempted to value other water

11. Estimates of the health burden and the economic costs of hepatitis and diarrheas have subsequently been developed by Ferreccio (personal communication) as an input to the EMOS wastewater treatment master plan study to be completed in late 1994. Using case data for 1986, Ferreccio estimates that typhoid represented only 8.8 percent of the direct health costs, while hepatitis represented 3.8 percent and diarrhea 87.4 percent.

quality improvements that could result from wastewater treatment either outside the SMR or in non-health categories. Such impacts could include, for example, amenity values of water use such as beach recreation in the downstream coastal area, or effects on fish and shellfish in coastal waters. Nor has the study adequately addressed the value of the water use rights for Santiago's treated effluents that EMOS could transfer to third parties assuming a well functioning water market in Chile. Recall that estimated willingness to pay for irrigation water in the Recoleta-Paloma-Cogoti system is US$0.10 per m^3, and water shares for other uses in the Maipo-Mapocho system are valued at US$0.16 per m^3 (para. 2.98). These figures are close to the estimated cost of treating Santiago's wastewater. In practice, however, farmer willingness to pay for *treated* wastewater for irrigation appears to be very low.

2.132 Another type of market failure has not been dealt with: the lack of willingness to pay on the part of urban water consumers for wastewater treatment, since in most cases the impacts occur in the form of externalities to the consumer. Elsewhere in Chile and other parts of Latin America, contingent valuation surveys have shown that WTP for urban wastewater treatment is very low (Ducci, 1991). Although such WTP studies have not been conducted in Santiago, it could be expected that WTP is positive in this unique case because *many of the impacts are already internalized.* The population is now well aware of the health impact of sewage irrigation in the SMR and the fact that 90 percent of the affected population lives in Santiago itself. As a consequence, corresponding water and sewerage tariff increases should meet with less public opposition than normally would be anticipated.

2.133 Finally, a number of intangible items enter into consideration when dealing with the impact of typhoid and cholera. Beyond productivity and economic development, in a developed society such as in Chile people's expectations are of a better quality of life with increased life expectancy, and reduced illness, pain and suffering from preventable diseases. Similarly, there is concern on the part of national policy-makers to protect the country's image abroad so as to ensure ample opportunity for fruit exports (which grew at over 33 percent in both 1990 and 1991) and tourism (currently growing at 18 percent per year) and open the door to possible free-trade agreements.

2.134 Taking into account these additional considerations, together with the valuation results of the study, it is not surprising that many metropolitan and national policy makers now view wastewater treatment as a necessary and viable environmental infrastructure investment.

<u>The Next Priority -- Industrial Discharge Control</u>

2.135 Assuming that the full wastewater treatment option is implemented in phases over the next 10 to 15 years (a normal design and construction period for works of this magnitude), the risks of transmissible diseases such as cholera and typhoid would be minimized and would cease to be a water pollution problem in the SMR. Unrestricted irrigated agriculture would be expected to continue downstream of treated effluent discharges. A number of new or emerging problems linked to industrial wastewater discharges would then assume much greater significance. These would likely include:

(a) potential problems linked to the irrigation of food or forage crops with chemically polluted water, posing health risks to end consumers or agronomic risks to crop production; municipal wastewater treatment systems designed to minimized risks from pathogens may not provide adequate security from chemical pollutants and additional, advanced treatment processes may be required;

(b) uncontrolled industrial discharges into municipal sewers can cause damage to sewer pipes and interfere with the effective operation of biological wastewater treatment processes; and

(c) municipal wastewater treatment plants produce large quantities of sludge that tend to concentrate chemical pollutants where there are uncontrolled industrial discharges to sewers; land application of sludge in agricultural areas is a common municipal sludge disposal method that carries the associated risk of chemical contamination of soils.

2.136 The concern with the risks associated with uncontrolled industrial discharges arises from the great concentration of industry in the SMR (see Table 2.18) and the fact that a special program for pretreatment and control of industrial discharges into the Santiago sewer system is yet to be agreed or implemented in Chile.

2.137 For an effective industrial discharge control program, greater attention should be given to the following actions by SSS, EMOS or other sewerage companies, and the private sector:

(a) SSS should move beyond the inventory stage for industrial discharges to the creation of a discharge registry and permit system that can be continually updated;

(b) in addition to setting discharge standards differentiated by industry category, SSS should complement the command and control approach with the application of economic instruments and incentives (e.g., introduce pollution charges and tradeable permit schemes, financial incentives such as access to special lines of credit, and technical assistance to priority industries, including development of technical guidelines and information on waste minimization options, cost-effective technologies, and demonstration projects to gain practical experience);

(c) SSS should provide assistance to industries for implementing self-reporting requirements, and develop a certification program for private auditing firms;

(d) EMOS should develop the capacity to supervise and provide spot checks on the self-reporting program and verify that pretreatment requirements are met prior to discharge to municipal sewers; and

(e) EMOS should establish sewer-use fees to industries based on volume and load of each industry's effluents, set to ensure that industries pay their fair share of the investment and operating costs of municipal sewerage and treatment systems.

Table 2.18: Major Industries in the Santiago Metropolitan Region, 1990

Type of Industry	> 50 Employees		< 50 Employees	
	Number of Factories	Number of Employees	Number of Factories	Number of Employees
Food	125	24,361	422	9,583
Textile	119	21,613	201	5,299
Chemicals	89	14,694	80	1,317
Plastics	78	9,211	95	2,545
Paper	59	12,931	115	2,890
Rubber	13	1,643	20	457
Basic metal industries				
- iron and steel	15	3,156	9	272
- non-ferrous	7	2,278	6	131
Totals	505	89,887	948	22,494

Source: BKH (1992).

2.138 In addition, clarification is needed with regard to responsibilities for controlling direct industrial discharges into natural water bodies and canals, including control over EMOS' effluents. Presently, SSS is responsible for control of industrial discharges in general; both SSA and SSS must authorize the operation of a polluting firm; SSA is responsible in general for environmental health protection from water pollution; the SAG can prohibit discharges that affect animals and crops; and the DGA is in charge of applying policies that protect water quality and coordinating the functions that other public institutions carry out. Finally, CONAMA and CEDRM should, under the Basic Law for the Environment, play a major role in coordinating water pollution control planning and actions at the level of the SMR, particularly through implementation of environmental impact assessment (EIA) procedures.

Integrated Water Quality Management

2.139 Given the evolving regulatory and institutional framework for water resources planning and management in Chile, the time is ripe to address a number of issues related to the integration of water quality management into the broader framework. This study has highlighted a number of these issues as they relate to the Maipo-Mapocho Basin.

2.140 The present Water Code virtually ignores quality issues. The new Basic Law for the Environment in combination with the proposed modifications to the Water Code, if passed, could create new institutional structures to deal with combined water quantity-quality problems. It will be important to ensure consistency and complementarity between these legislative measures. However, the question of water quality is not explicitly dealt in either the Basic Law or the Water Code proposal and will require considerable additional effort to develop a new regulatory framework for water quality management. The framework should facilitate managing relations between water uses and users at the basin level, especially with regard to environmental interactions. New mechanisms and institutions are needed to help resolve water quality conflicts -- through negotiation or litigation.

2.141 There is a need to harmonize regulatory responsibilities for water quality management at the national, regional and local levels, and strengthen the institutional capacity for monitoring and enforcement of water quality regulations and standards for competing uses, such as municipal and industrial wastewater disposal and irrigation. In the future, these responsibilities could pass to the regional environmental commissions (e.g., CEDRM) or in part to proposed river basin corporations. The latter proposal seems the most sensible -- to have water quality treated as an integral part of basin-wide water development along with other intersectoral issues.

2.142 At present there is no means of imputing an environmental value to the quality of water resources. Consideration could be given to the application of a Pigouvian tax on wastewater discharges (effluent tax) that would stimulate willingness to pay for wastewater treatment, provide a means of raising revenues for water quality management programs, and could also be used for wastewater treatment plant construction grants. In particular, such a measure could help overcome political reluctance to invest in municipal wastewater treatment because of the corresponding water tariff increases mandated by the Sanitary Code. In the event that full wastewater treatment is not the preferred pollution control alternative for either political or economic reasons, then effluent tax revenues should be applied to inspection and control programs to help ensure their institutionalization and effective implementation.

I. Summary of Recommended Actions

Legislation

2.143 Chile has just approved the Basic Law for the Environment, and proposed modifications to the Water Code are currently in parliament. These important legislative changes could provide an opportunity to develop appropriate policies for water quality management within a broader water resources management framework. The framework should be designed to facilitate managing relations between water uses and users and help resolve water quality-quantity conflicts. The Bank-supported Bio-Bio River Basin Project can assist in refining the framework over the next few years.

Institutional Reform

2.144 Priority should be given to developing a strong institution for overall management of surface and ground water and of quality control. The DGA is the natural rector institution, and its powers and resources should be examined to determine if they are adequate for the job. Better coordination for control of water pollution at source is needed between DGA and SSA, and with SSS, EMOS and SAG. Implementation of water quality policies, monitoring and studies should be decentralized to the regional or basin level.

2.145 CONAMA at the national level and CEDRM at the regional level have been created to strengthen environmental management, conduct research and policy analysis, and coordinate monitoring and enforcement activities undertaken by sectoral agencies. In the area of water quality management, CONAMA should work closely with DGA to ensure that water quality issues are effectively integrated into the overall regulatory and institutional framework for water resources. At the level of the Maipo-Mapocho Basin, CEDRM should actively assist DGA in defining and setting up a basin corporation. An interagency water quality task force could be established to recommend specific coordination mechanisms at the national and regional/basin levels.

Studies

2.146 An on-going EMOS study to define wastewater treatment options for the SMR will be completed at the end of 1994 and should receive priority attention by the new administration. The EMOS study should provide the technical basis for developing a strategic long-term water quality management plan for the Maipo-Mapocho Basin. The latter study should be given priority and should concentrate on consolidating the policies and programs for the prevention of cholera and on developing industrial discharge control policies and programs.

2.147 Beyond the present analysis of microbiological water pollution, a more comprehensive evaluation of the health effects of different forms of water pollution would be desirable. This includes the analysis of possible contamination of the food chain from toxic water pollution, a socio-economic analysis of the affected population, and attention to hygiene education and other long-term preventive measures.

III. THE NET BENEFITS OF AN AIR POLLUTION CONTROL SCENARIO FOR SANTIAGO[1]

A. Scope and Analytical Framework

3.1 The population in the Santiago Metropolitan Region faces most of the adverse consequences of air pollution there. The same population will, most likely, face most of the costs of controlling pollution. In this context, a cost-benefit analysis of a number of proposed air pollution control options is undertaken. In this analysis, it is assumed that the distribution of costs and benefits between different individuals need not influence the choice of control strategies. According to the compensation criterion, a policy option is considered desirable if there are net benefits, meaning that those gaining from this option could compensate the losers and still remain better off than before. It is important to be aware of the shortcomings of this approach when costless transfer mechanisms for the compensation of losers are not available.

3.2 The analysis focuses on decision alternatives and the costs and benefits of certain control options, rather than the total costs of air pollution. No complete ranking of emission control options for Santiago is given; instead a package of potentially attractive control options is evaluated. Using estimated consequences of various options, the cost effectiveness of alternative strategies is compared in terms of providing improved health to the population of Santiago. First, a ranking of alternative strategies is based on a proposed prioritization amongst various health effects. Then, tentative values for the health effects in question are presented. Needless to say, it is not a straight-forward task to find universally accepted routes towards valuing effects such as respiratory disease and heart attacks, let alone premature deaths and learning disabilities for children. Most estimates are based on "direct cost estimates" such as the cost of treatment and the cost of lost days, where the latter is estimated as the value of lost productivity.

3.3 The study attempts, under the limits of present knowledge and analytical resources, to estimate costs and benefits of a pollution control strategy, including the prioritization between components of the strategy. While the study displays remaining shortcomings in the knowledge base, it is the first to estimate the consequences of a realistic pollution control program, using a dispersion model to estimate changes in health benefits based on changes in exposure - resulting in a full-fledged cost benefit analysis.

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1. This chapter was written by Gunnar S. Eskeland based on the findings of background papers prepared for this study by Bart Ostro, Jose Miguel Sanchez, Pablo Ulriksen, and Christopher S. Weaver. References to these background papers are given at the end of the report. The chapter also benefitted from research funded by the World Bank's research committee, undertaken by Eskeland, Ostro, Sanchez and Carlos Arranda.

3.4 Importantly, since many suspected health effects of air pollution are not yet quantified in the literature, the estimated health benefits presented here should be seen as very conservative. Also, there may be more to air quality improvements for the population of Santiago than the expected improvements in health. The reduced cost of soiling for households and firms is one of them; another is the value of amenity improvements, such as improved visibility to the surrounding mountains. A complete list would also include consequences for vegetation in agriculture and in the wild, as well as consequences for tourism within and outside Santiago. The value of these other effects could be estimated with the help of various methodologies. Clearly, several important categories of *positive benefits* of air pollution control are excluded from the analysis. While health effects represent a major category of the benefits associated with air pollution control, no attempt was made to estimate other categories of benefits. However, it should be noted that assumed health effects have been the driving force of emission control programs in industrialized countries (even though cost/benefit analysis has often not been employed).

3.5 Assuming that the consequences excluded from the analysis would, in aggregate, be positive, the benefit estimates provide lower bounds for benefits, and the estimates of the attractiveness of emission control options are thus biased downwards. Furthermore, inclusion of other benefits could change the prioritization of options, since it would change the prioritization of pollutants. For instance, if additional benefits are associated with visibility, then this would place a greater emphasis on dust, and in particular on the sources of dust that play little role in exposing the population to health risk, such as windblown dust and dust from unpaved roads. It could also increase the importance of gasoline vehicles if ozone and CO is found to be important in limiting visibility.

3.6 Finally, air pollution has been examined from the perspective of the population of Santiago. Of course, benefits and costs accruing to others could also be included. However, external benefits of pollution control should lead to direct incentives between jurisdictions making choices that affect each other. Thus, if Chile provided environmental benefits to other countries while controlling local air pollution then Chile should be given the incentives that would make such export of environmental services attractive. In the case of an international policy to reduce global warming, this would have to take the form of a subsidy for emission control programs in cities like Santiago, or fees for cities levied on total emissions. For a given locally motivated emission control program, such incentives would increase the priority given to emission controls in general, and in particular to those reducing methane and carbondioxide. Such incentives would allow consistency and coordination between locally and globally motivated emission control programs.

B. The Air Pollution Problem in Santiago

3.7 The population of Santiago has grown from 1.4 million in 1960 to an estimated 4.8 million currently, representing 37 percent of the country's population. Increased population densities and associated levels of economic activity have led to increased pollution. The topographical, climatic, and meteorological conditions in Santiago make air pollution worse in the winter months, particularly May through August. In this period, particulate concentrations in Santiago are among the highest in any urban area in the world. The particles include a large proportion of particles less than 2.5 microns in diameter, including sulfates, and are thus of great concern for public health, since they have the potential to be inhaled deeply into the lungs.

3.8 For most air pollutants in most cities, ambient air concentrations result from a multitude of actions by individual polluters. Thus, ambient air quality standards (as opposed to emission standards, or technology standards) can best be viewed as expressions of targets for the collective efforts of maintaining an "acceptable" air quality. For a city's population, they represent a benchmark against which to assess the progress made by the agencies charged with pollution control policies. Similarly, for those agencies, they can provide a means to exercise the authority with which they can strive for pollution control efforts, even though the ambient standards do not themselves play a role in enforcement. In addition to this, pollution control agencies have the short-term task of protecting a city against the consequences of particularly poor air quality situations. Short term instruments will generally include policies that reduce emissions (shut down factories, redirect traffic), as well as policies that reduce exposure (such as advising against outdoor exercise for children, or closing schools). Table 3.1 shows ambient air quality standards for Santiago, which are generally in line with those applied worldwide.

Table 3.1: Chilean Ambient Air Quality Standards*

	1 hr	8 hr	24 hrs	1 year
Total suspended particles			260	75
Respirable suspended particles			150	50
Carbon monoxide (CO)	40,000	10,000		
Ozone (O_3)	160			
Nitrogendioxide (NO_2)			100	

Source: CEDRM, 1992. * Concentration in $\mu g/m^3$

3.9 These standards are in violation for total suspended particulates (TSP), respirable particles (PM-10), and carbon monoxide (CO) in the winter months and ozone in the summer months (O'Ryan, 1993). The daily ambient air quality standard for PM-10 was violated 100 days in 1990, 69 days in 1991, and 60 days in 1992.

3.10 For PM-10, there is also a standard set for the annual average, which is exceeded by about 110 percent. Rough comparisons, subject to great uncertainty due to variation in measurement, indicate that the annual particulate concentrations in Santiago are about 50 percent higher than those observed in Bangkok and about 30 percent higher than those observed in Jakarta -- about on a level with those observed in Mexico City. The levels observed during winter months are about 70 percent of the levels observed in London in 1958/59 through 1965/66, and 225 percent of the levels observed in London 1966/67 through 1972/73[2].

3.11 Between 1990 and 1992, it is a matter of debate whether the air pollution situation has actually improved or not. The ICAP, an index for air quality in Santiago, records the daily status of air quality. ICAP is a function of ambient particulate pollution, summarizing with a single number whether the day can be categorized as good, regular, bad, critical, or dangerous. Table 3.2 shows that in 1990, air quality was bad or worse on 20 days. The air is categorized as good if pollutants are below the standard, i.e., ICAP is less than 100. Respirable particles, or small dust particles, by far the most serious pollutant in Santiago, show a slight decline for most monitors with the highest readings, but are fairly stable in readings averaged across monitoring sites. A pre-emergency was declared 11 times in 1990 and 1991, and 14 times in 1992. An emergency was declared two times in each of the three years (Table 3.2). In pre-emergency and emergency situations, schools are closed, and parts of the vehicle fleet and industries are prevented from operating. In terms of monthly averages, a consistent decline is observable for PM-10 in the winter months if 1989 is included in the comparison, whereas for 1990 through 1992, the picture is mixed.

3.12 Chilean law has long recognized the right to live in an unpolluted environment, and the "Ley sobre Bases Generales del Medio Ambiente" establishes the National Commission for the Protection of the Environment (CONAMA), the polluter pays principle, as well as institutional responsibilities in terms of standards and programs. In Santiago, the Special Commission for Pollution Prevention and Reduction in the Metropolitan Region (CEDRM), established in 1990, works with ministries when specific courses of actions are recommended. The regulations establishing emission standards are based on health ministry legislation. The ministry's metropolitan environmental health service also operates the city's air pollution monitors. The special commission sponsors studies, computes and publishes air quality data, and has devised emergency measures (to reduce pollution and exposure immediately on "crisis" days) as well as a master plan. The master plan aims at producing consistent improvements, allowing time for studies and implementation.

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2. The level of air pollution in London fell dramatically over these 14 winters, from 270 to 80 micrograms/m^3, compared to Santiago's 180 micrograms per cubic meter of PM-10 during the three winter months. This experience has probably shaped common perceptions, scientific investigations, and air pollution control programs worldwide.

Table 3.2: Number of Days in Which the Air Quality Index (ICAP) was Violated in Santiago

Month	ICAP 100 (Regular, and worse)			ICAP 300 (Bad, and worse)			ICAP 500 (Exceeding *Peligroso*)		
	1990	1991	1992	1990	1991	1992	1990	1991	1992
January	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0
March	1	0	1	0	0	0	0	0	0
April	9	7	5	2	1	0	1	0	0
May	16	16	12	5	6	2	1	0	0
June	15	19	19	11	9	9	3	1	0
July	24	17	24	8	5	6	0	0	3
August	18	8	16	6	0	3	1	0	0
September	4	2	7	1	0	6	1	0	0
October	1	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0	0
TOTAL	100	69	84	33	20	20	7	7	3

3.13 In terms of emission reduction initiatives, emission standards are in place for fixed sources, and there are plans to reshape these into tradeable permits. From 1992 onwards, cars are required to meet emission standards equivalent to those of the US EPA for 1983. The lead content in leaded gasoline is to be reduced to 0.18 g/l by 1995. Also, the city has obtained at least one flexible tool with which to handle the problem of old, polluting buses. By soliciting bids from potential operators about the type of vehicles, routes and fares, the government has been able to reduce congestion, improve the standard of buses, increase load factors, and reduce fares. Finally, in terms of energy use, fuels are not subsidized and electricity is more than 50 percent hydro-based. Plans for a natural gas pipeline from Argentina could make large quantities of cleaner fuel available in a few years to be used by households, firms, and the transport sector.

C. Emission Inventory and a Proposed Control Strategy

3.14 The concentrations of pollutants in ambient air are the main indicators of the environmental damages from pollution; however, the flow of emissions into the airshed must be assessed to analyze *control options*. This study has been based on updating and improving established data on emissions in Santiago. Thus, an emission inventory for Santiago in 1988 (IES-88), with additional research from 1990 and 1992, was the benchmark before the work of Ulriksen et al. (1994) and Weaver et al. (1993)

done for this study. In general, the data are based on a detailed categorization of polluting sources combined with local and international research to project emissions[3].

Table 3.3: Emission Inventory, annual tons

Source	PM-10	SOx	NOx	VOC	CO
Mobile sources					
Cars	411.6	1193.7	11662.1	28126.2	242845
Taxis	32.1	93.0	908.8	2191.8	18925
Buses	1860.6	2391.5	5047.5	1394.9	5819
Trucks	394.1	1176.2	3848.8	1413.3	5788
Subtotal	2698.4	4854.4	21467.2	33126.1	273377
Point Sources					
Ind.Processes	607.5	2792.6	568.3	17.4	78
Ind. Boilers	2746.2	11513.0	2586.1	444.7	11509
Heating Boilers	358.2	921.6	213.8	22.7	532
Bakeries	150.1	51.1	53.5	26.4	632
Subtotal	3862	15278.3	3421.7	511.2	12751
Group Sources*					
Street Dust	17355.8		61.5		
Residential Wood-burning	1506.7		190.0		
Subtotal	18862.5	204.0	251.5	14280.2	5311
Total	25422.9	20336.7	25140.2	47917.5	291440

* For group sources, only part of the breakdown is shown. Evaporative losses from cars, 6,592 tons, are categorized among group sources.

3.15 Table 3.3 shows the present emission inventory for respirable particles (PM-10), sulfur oxides (SOx) and nitrogen oxides (NOx), Volatile Organic Compounds (VOC) and Carbon Monoxide (CO). Some results in other cities are confirmed for Santiago: for respirable particles, mobile sources play only a minor role, or about 11 percent of total annual emissions.

3.16 Importantly, the table fails to reflect some differences between sources: particles from vehicles, as well as other combustion sources, have been found to play a

3. For emission factors and control options, see Turner, Weaver and Reale, 1993. For emission inventory and dispersion model, see Ulriksen, Fernandez and Munoz, 1994.

greater role in ambient pollution than in the emission inventory[4], while the opposite holds for resuspended dust from roads (unpaved as well as paved); it plays a dominant role in most inventories over aggregate emissions, but will play a smaller role in ambient air exposure. This lack of proportionality stems from fact that resuspended road dust may have a shorter "flying time" on average. Also, it tends to have a spatial distribution that is more towards the periphery of the urban area, thus with less effect on population concentrations than the other emitted sources. The treatment of resuspended dust represents one of the major challenges in terms of ambient modelling and the evaluation of control strategies, since the particle control strategies are emphasizing the share of particle emissions from industrial and vehicular sources, which together are responsible for only 25 percent of particle emissions. Presently, knowledge about emissions from roads is poor, as is knowledge of the cost effectiveness of measures to control them (traffic restraints, paving, watering and washing, land-use changes, treeplanting). In the present study no control strategies for these emissions are analyzed.

3.17 For NOx, VOC and CO, vehicles are important emitters. Vehicles emit about 85 percent of NOx, 69 percent of VOC and 94 percent of CO (Table 3.3). NOx is a significant pollutant in itself, with direct health effects. Also, together with VOC, it contributes to the generation of ground-level ozone, a powerful oxidant with harmful health effects. Similarly, as acids, NOx and SOx will contribute to corrosion, acid rain and damage to vegetation and ecosystems--consequences not analyzed in this study.

3.18 The *Control Strategy*. With a base case scenario established by the updated emission inventory, a "package" of control measures was devised, with the aim to quantify its implications for annual emissions of the main air pollutants. Important criteria for the control measures were that they should have an important impact on emissions, that the basis for assessing their costs and effects on emissions should be reasonably well developed in advance, and that they should not be seen as rejected *a priory* for reasons of costs or feasibility. Apart from that, the Control Strategy does not itself emerge from optimization over a complete and detailed list of options for emission controls in Santiago. As a package, on the other hand, it may be disentangled later, for analytical as well as practical purposes. Thus, the analysis of the package will allow revelation of critical criteria (important pollutants, important sources, important measures, important locations). Furthermore, it will allow the calculation of figures such as priority weights by emitted pollutants, which can be used for evaluation of a more comprehensive range of control options.

4. Analysis of particulates: Prendez et al. (size composition, respirability), and Gil (chemical composition, mutagenicity, carcinogenicity).

3.19 The initial set of measures analyzed for the control strategy were:

- **Light duty gasoline vehicles**: Emission standards for light duty gasoline vehicles, which took effect in September 1992.

- **Light duty gasoline vehicles:** Addition of 15% oxygen-additives (MTBE) to gasoline, eliminating lead.

- **Buses and Trucks:** Requiring new buses and trucks to be equipped with diesel engines meeting US 1991 emission standards;

- **Buses:** Use of low-emission natural gas in buses, in place of diesel engines;

- **Point sources:** The new particulate matter concentration limits for stationary sources, as well as allowing emission trading, with compliance sought through emission controls.

- **Point sources:** Elimination of wood-burning by commercial and industrial facilities, substituting distillate oil or natural gas.

3.20 Detailed analysis of these options, and in particular the quantification of emission reductions and costs, is found in Weaver et al. 1994. Emission figures relate to annual emitted tons of each pollutant in the emission inventory. To correspond to these figures, capital costs are annualized and combined with strategy-related increases/reductions in operating costs.

3.21 The *Control Scenario* is composed of emission standards for light duty vehicles, emission standards for trucks, the use of compressed natural gas for buses, and conversion of wood-burning industrial sources to distillate fuel oil. The reasons for composing this package are as follows. Emission standards for light duty gasoline vehicles are already in place, so that the vehicle fleet is changing over the replacement cycle. MTBE will then mainly have the effect of reducing lead from the uncontrolled part of the fleet. The scant lead data examined to date do not indicate that atmospheric lead is a major problem (and it will decline with the change in the vehicle fleet); however, this should be subject of further examination. For buses, conversion to compressed natural gas (CNG) proved more cost effective than the diesel conversion to satisfy proposed standards. For trucks, CNG conversion is less viable than for buses, since heterogeneity of the fleet and its use patterns make both the one-time conversion and the refilling more complex for the truck fleet. It remains to be seen, however, whether emission standards (in combination with pricing and other measures), are still an adequate implementation mechanism, leaving operators free to choose technical solutions, including CNG conversion. Thus, while this analysis indicates that buses would respond by converting to CNG, and trucks by adopting modern diesel engines, instruments should be developed in such a way that operators can provide feedback on what they find to be low-cost solutions. Table 3.4 shows cost calculations for the four strategies included in the *Control Strategy*, per vehicle and industrial application.

Table 3.4: Summary of Measures in Control Strategy

Each polluting unit	Usage	Costs (US$) Investment	Fuel (annual)	Incremental Cost Effectiveness US$/ton/PM10
Light Duty Gasoline Vehicles	15,000 km	630	- 69	36,900
Heavy Duty Trucks	30,000 km	1,500	214	16,500
Buses, CNG Conversion	60,000 km	4,000	0**	17,356
Conversion from Wood, Fixed Sources*	440 ton	10,980	7,212	7,843

* For an artificial average unit. Utilization in tons of wood per year.
** Gas price unknown, savings estimated at zero but positive savings likely to result.

3.22 For industrial sources, preliminary analysis indicates that very minor emission reductions (200 annual tons) will occur as a result of the 112 mg/Nm^3 standard now being applied (Weaver et al.). The reason is that very few polluters are presently in violation of such an emission limit. A tighter future standard of 56 mg/Nm^3 would produce reductions of about 413 annual tons, but these emission reductions may be lost if the quotas are made tradeable, which is the intention. Thus, while it is clear that tradeable quotas will produce cost savings, it appears that quotas need to be tighter if emission reductions are to be produced. On the other hand, emission control devices as well as fuel substitution can produce emission reductions from industrial sources in the range of US$2,000 to US$8,000 per ton PM-10 (Weaver et al, 1994, and O'Ryan, 1993). As an illustration, we have chosen conversion from wood-burning to distillate (fuel oil number 2).

3.23 Annex 3 shows the estimated effect of a control scenario on emission coefficients from the various sources, and Annex 4 shows the complete inventory, comparing the base case with the control scenario. Table 3.5 shows the costs of the control scenario, and relates these to the changes in emissions of PM-10, the most important pollutant. Annual costs for the Control Strategy as a whole amount to US$46 million. The *Control Strategy* would buy, as shown in Annex 4, reductions of 3,831 tons of PM-10, 12,336 tons of NOx, 33,168 tons of VOC, and 1,639 tons of SOx.

Table 3.5: *Control Scenario*: Costs and PM-10 Reductions

	Vehicles			Point Sources: Convert Wood Burning to:		Combined
	1. Gasoline Vehicle Standards	2. Diesel Truck Control	3. CNG Buses	4. Distillate Fuel Oil	5. Natural Gas	Control Strategy (1+2+3+4)
Removes (t/yr)	369	271	1,752	1,438	1,170	3,831
Costs Mn US$/yr	14	4	30	11	19	60
Thousand US$/ton*	37	17	17	8	15	16

*All strategies also have effects on other pollutants, so the costs per ton of PM-10 is not necessarily an important indicator. Sources: Weaver et al, Ulriksen et al.

3.24 Using the costs per PM-10 ton as a metric, emission standards for gasoline vehicles are the most expensive, at US$37,000 per ton. This strategy is, however, quite effective in reducing emissions of NOx, VOC, and CO, so it is not necessarily an unattractive option. Point source conversion to distillate oil, in contrast, has the lowest cost in terms of dollars per ton PM-10.

3.25 Energy Pricing. As the preceding discussion has shown, emission control requires strategies that are comprehensive in coverage, including sectors with many independent agents that are difficult to influence with instruments based on monitoring. Then, strategies that change behavior with more subtle means, such as taxes on inputs, may provide attractive opportunities. Table 3.6 shows results of recent World Bank research (Eskeland et al. 1994) on the responsiveness to price changes of emissions from manufacturing. It shows that PM-10 emissions will be reduced with increases in user prices of electricity and wood-fuel (the most important fuel in the "grouped fuels" category).

3.26 Important results of the analysis were that demand for aggregate energy in Chilean manufacturing is quite responsive to prices, with an elasticity of -0.63, implying that emissions of all pollutants will be reduced by 6.3 percent at a 10 percent increase in all energy prices. The table also shows how relative energy prices can be exploited: a reduced price of fuel oil will reduce particulate (and PM-10) emissions, due to the positive cross-price elasticity with electricity, which is assumed to carry more particulates at the margin. Lower prices of fuel oil would lead to increased emissions of sulfur, however, so the prescribed strategy would rather be higher energy prices in general, and particularly for electricity and wood fuel.

Table 3.6: Chilean Manufacturing: Emission Elasticities with Respect to Fuel Prices

	Electricity Price	Fuel Oil Price	Coal Price	Diesel Price	Price of Grouped Fuels	Natural Gas Price	TOE Price
Particulates (TSP)	-.37	.25	.07	-.01	-.58	.15	-.63
SO_x	-.15	-.22	.01	-.08	-.29	.09	-.63
NO_x	.12	-.59	-.02	-.01	-.18	.06	-.63
VOC	.26	.03	-.55	.53	-1.02	.18	-.63
CO	.25	.22	-.69	.64	1.26	.22	-.63

3.27 Summarizing this section, even in terms of *relative* merits of the various components of this control strategy, no unique ranking (and no cost effectiveness measure) can be established before examining effectiveness in producing environmental improvements. Such improvements will be related to improvements in public health (though this is by no means a comprehensive measure). To do this, we first need to examine effectiveness in producing ambient air improvement.

D. Dispersion Modelling and Exposure: Base Case and Control Scenarios

3.28 A dispersion model of the Santiago airshed is used to estimate ambient pollutant concentrations across the city (distributed over grid cells of 2 x 2 kilometers) under alternative scenarios for emissions. The model, calculating concentrations of the various pollutants in each cell, with emissions in all cells as inputs, is of the form:

$$\frac{dM_{ij}}{dt} = Q_{ij} - \sum_{P} \Phi_{ij}^{P}$$

where M_{ij} is the mass of pollution in cell (i,j), Q_{ij} is the rate of emissions of the pollutant in the cell, and Φ_{ij}^{P} is the net flow of pollution from the cell through its P walls.

3.29 The model, which is built on research and development over many years, employs data on meteorological conditions, and uses daily, weekly, and seasonal patterns in weather and emissions to simulate the functioning of the airshed. Furthermore, it employs great detail in terms of geographical distribution of emissions. Fixed sources are given, to the extent possible, by specific location, group sources (such as residences) are allocated according to functional criteria, and emissions from mobile sources are constructed and distributed on the basis of traffic counts and flow models, distributing traffic over 3,000 arcs of the city's transportation network. Lastly, background levels are accounted for in the calibration process.

3.30 The simulation of *annual average concentrations* is performed through the modelling of pollution over 50 days, with modelled weather conditions constructed to be representative of weather conditions throughout the year. For the base case scenario, the dispersion model is calibrated to reproduce, approximately, the concentrations from the monitors in the city. Thus, for the base case scenario, the main output of the dispersion model is to produce ambient concentration levels for the parts of the city in which there are no air pollution monitors (i.e., not in the center or in the northeast)[5]. For the control scenarios, the dispersion model is used to estimate the changes that the projected emission reductions may produce in terms of ambient concentrations.

3.31 The calibration itself is an important part of the dispersion simulations. Since a calibration is needed to force a model to reproduce monitored ambient conditions, the model itself cannot be used as judge in a controversy about the emission inventory. In Santiago, as in many other places, uncertainty remains about emissions of resuspended dust and their role in the atmospheric pollution. In performing sensitivity analysis, the main consequence of reducing the role of resuspended dust in the emission inventory by 50 percent proved to be that the role of the other sources in the inventory is increased. Consequently, when the model is recalibrated to produce observed ambient concentrations, control measures that reduce emissions from other sources increase their effectiveness in improving the ambient air quality. For this reason, the choice of a "high" estimate for emissions of resuspended dust implies a conservative estimate of the benefits of control measures addressing mobile and point sources.

3.32 To approximate the extent to which the population is *exposed* to the ambient concentrations across the city, residential densities are used as basis in the exposure calculation. For this reason, population-weighted figures are given when summary statistics on ambient concentrations are reported[6]. This exposure model is, indeed, a quite simplistic one, since people are also exposed when traveling, and while at work. It is, however, an improvement over the standard assumption that people are exposed to downtown concentrations or to unweighted city-wide averages. In terms of

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5. Details on the dispersion model and the calculations are found in Ulriksen, 1994.

6. The population weights are, for each grid cell, the share of Santiago's population assumed to be residing in that cell. For the purposes of comparisons, population-weighted averages will generally be lower than monitored readings (which invariably emphasize the central and polluted sites), but higher than unweighted averages from dispersion models (which emphasize more peripheral, less polluted, less populated areas). In the scientific literature, one often assumes that city-wide averages are about one third lower than the readings at central monitors. This corresponds well with the performance of our dispersion model for Santiago: In the Base Case Scenario, the unweighted average ambient concentration is 69 percent of the ambient concentration at central monitor locations, and 85 percent of exposure weighted concentrations.

policy relevance, the weighting implies a priority for strategies that concentrate ambient reductions in areas with high residential densities. Tables 1 and 2 of Annex 5 show the population distribution of Santiago by *comuna* and how the population has been distributed by grid cell, to be matched with the results from the atmospheric dispersion model.

Table 3.7: Improvement in Concentrations when the *Control Scenario* is Applied

	Units	Assumed Standard	Base Case	*Control Scenario*	Exceedance Reduction**
PM - 10	$\mu g/m^3$	41.25	112.61	104.18 (-7.4%)	8.43 (-7.4%)
SO_x	$\mu g/m^3$	85.8	61.46	58.73 (-4.4%)	.16 (-.3%)
NO_2	ppm	.053	.066	.049 (-25.8%)	.013 (-19.7%)
Ozone	ppm	.0817	.170	.131 (-22.9%)	.0365 (-21.5%)

The *Control Scenario* is not a removal of all excess concentrations, but the result of specific interventions. See Table 3.5.

* Population-weighted averages across city, by dispersion model.

** "Exceedance reductions" measures changes in ambient concentrations only when they occur at levels exceeding the standard. Source: Ulriksen, 1994; Ostro, 1994; WB calculations.

3.33 Table 3.7 shows the results from the dispersion and exposure model for the Base Case and Control Scenario. It also shows the standard against which these concentrations can be compared, and which will be used as a threshold value in the calculation of health effects (to be conservative, it is assumed that health effects are not present when ambient concentrations vary within a range of compliance, see below). The value shown in the last column, termed "Exceedance Reduction," is the part of the improvement that occurs in locations that are not in compliance with the ambient standard. For PM-10, which is by far exceeding the standard across the city, the exceedance reduction, 8.43 micrograms/m^3, is the same value as the (population weighted average) ambient air improvement, which appears as the difference between Base Case and Control Strategy concentrations. For SOx, NOx and ozone, average concentrations are exceeding standards, but important parts of the city are in compliance. Thus, only parts of the reductions in ambient concentrations are also reductions in excess concentrations.

3.34 The use of a threshold value in the exposure calculations has an important effect in terms of policy directions, distinct from changing the overall magnitude of the benefits from ambient air reductions. It introduces a curvature in the benefit functions, which for given average concentrations will generally increase the importance of pollutants that are unevenly distributed, and raise the importance of reductions in areas with high concentrations. Earlier applied studies have generally not been able to assess the curvature of dose response functions, let alone threshold values (see Ostro, 1994b). However, the higher priority to "hot spots" with higher concentration probably reflects well how policy makers would direct their resources.

Table 3.8: Effectiveness in Reducing Exposure: *Localized* Emission Reductions

	Effectiveness: Micrograms/m^3 per thousand ton emissions reduced	
	On Central Monitors	On Population Weighted Exposure
Central Area Emissions	2.42	2.61
North-East Emissions	4.30	2.93
South-West Emissions	.50	.74

3.35 The dispersion model may also allow us to analyze more detailed questions for strategy formulation. One such question is the extent to which certain initiatives, because of the location of their emission reductions, generate greater reductions in population exposure than others. If this is the case, then those initiatives would be valued more highly than other initiatives per ton of emission reduction because each ton generates more health effects. In Table 3.8, directed emission reductions in the city center are compared with emission reductions in the north-eastern and south-western parts of the city. The first column, "On Central Monitors" shows that north-eastern emission changes are almost twice as productive as central emission changes in producing concentration reductions at central monitors. Centrally located emission reductions are, again, about five times as productive as reductions in the South-West, in terms of reducing concentrations at central monitors. The effects on population weighted exposure, in the last column, is more important. In terms of population-weighted concentrations, central and north-eastern emission reductions have about the same productivity (i.e. concentration reductions per ton emission reductions), while emission reductions in the South-West result in exposure reductions that are much smaller (about a third). The differences reflect, mostly, predominant wind patterns. Winds from the South-West are not unimportant during daytime, but matter less than those from the North-East when averaged over the 24 hour cycle, and then year, as here.

3.36 In Table 3.9, the four component strategies of the *Control Scenario* are analyzed with this in mind. The latter column shows that the component strategies do not vary by much in terms of exposure reductions per ton of PM-10: the least effective is the strategy for fixed point sources, which reduces population weighted concentrations by 2.08 micrograms per thousand ton emission reductions, or 11 percent less than the strategy that is most effective in terms of exposure reductions per emitted ton - the truck strategy - at 2.35. Thus, while truck emissions generate a geographical pattern that to a greater extent coincide with population exposure than other component strategies, the difference is not startling. In consequence, if strategies were to be based on uniform implicit values per emitted ton of PM-10 for these broad categories of emitters (and, consequently, equalize control costs), it would come very close to being a cost-effective program.

Table 3.9: Effectiveness in Reducing PM-10 Exposure: Comparison of Strategies

	Effectiveness: Micrograms/m^3 per thousand ton emissions reduced	
	On Central Monitors	On Population Weighted Exposure
Control Scenario	3.43	2.20
Fixed Point Strategy	1.90	2.08
Bus Strategy	3.63	2.28
Cars and Taxis	3.78	2.12
Truck Strategy	3.87	2.35

3.37 The table also shows how the component strategies compare in terms of effectiveness at centrally placed monitors, rather than in terms of population weighted exposure. The variation is greater (though still with the truck strategy being the most productive), illustrating that policies would be misguided by as much as 50 percent if evaluated by their estimated effect on central monitors, rather than by their effects on exposure (such policies would, then, be too lenient on fixed-point sources, since they would appear to be only 50 percent as effective as other component strategies).

3.38 These comparisons thus show that careful exposure modelling does not result in major policy refinements when broad strategies, such as those in the *Control Scenario*, are compared. The reason is that these strategies all have a geographically distributed pattern of emission reductions, patterns that result in similar exposure reductions. For directed emission reductions, on the other hand, the lessons are sharper: Emission reductions in the South-West may easily be worth only a third of emission reductions in the City Center or in the North-East (emission reductions in the South-East and in the North-West are likely to be even less productive, though calculations have not been performed). That result has important implications for the design of the proposed "Compensation system" (which is closer to an offset system than a system of tradeable permits, since it will be intensively managed). The calculations indicate that a Central "focus area", in which emissions are more tightly controlled, should stretch more to the North-East than to the South-West. Furthermore, if purchases of emission permits into the central area were to be allowed at a premium, the premium should be quite large, perhaps so that one needs to reduce emissions by two or three tons in the Western/Southern Zone in order to increase emissions by one ton in the Central/Northern/Eastern Zone. The design of the compensation system will have to, of course, carefully weigh the costs of complexity against the returns to sophistication. It appears clear, however, that treating emissions as equal across the metropolitan grid (34 kilometers by 34 kilometers) would be overly simplistic (unless if complemented by separate mechanisms directing/restricting certain trades).

E. Estimation of Health Effects

3.39 With the prospect of quantified changes in ambient air concentrations, the health effects associated with the changes can be estimated if one has established an association between air pollution exposure and the related health effects often called dose-response functions. In the peer-reviewed scientific literature, dose response functions have now been estimated (though mostly in industrialized countries) for a variety of health end points, (e.g., premature mortality, respiratory hospital admissions, asthma attacks, eye irritation), using different data sets and methodologies. Though the studies cover a number of health endpoints and pollutants (ozone, NOx, various measures of particles, such as PM-10), they cannot claim to provide comprehensive coverage.

3.40 In this study, dose response functions are based on a literature review (Ostro, 1994), that also provides a detailed discussion of the approach[7]. Results from time-series studies were used to avoid many of the problems with confounding effects in cross-sectional studies. This will, most likely, result in conservative estimates of the health effects, since there may be additional effects associated with long-term exposure which are not captured in the time series studies. Health endpoints suspected but not identified in these dose response functions may be various types of cancer, development of asthma, and deterioration of lung function due to cumulative effects of ozone. Apart from health effects that have, so far, escaped detection with statistical inference from time series studies, it is likely that the magnitude of the effects for some health endpoints is underestimated due to the difficulty of capturing long-term, cumulative effects.

3.41 Dose response functions will generally indicate the slope of a partial relation, suggesting the health effects of changes in ambient concentrations, ceteris paribus. Thus, to the extent possible, the effects of such confounding effects as other pollutants, weather, etc., have been isolated when making inference about the effect of changes in pollutant concentrations.

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7. Ostro, 1994b reviews the literature, proposes a methodology, and provides an application to Jakarta, similar to the one used in this study.

BOX 3.1: Dose response functions in Santiago compared to other studies:

Recent reviews of mortality studies undertaken in industrialized country cities suggest that reduction of PM-10 concentrations of 10 microgram/m^3 is associated with approximately a one percent increase in mortality, while a meta-analysis suggests a range of .7 to 1.1 percent (Ostro, 1994, Dockery and Pope, 1994, Schwartz, 1994). Ostro (1994) reviews studies of premature mortality, finding an average effect of 0.96 percent increase in mortality per 10 $\mu g/m^3$ PM-10.

A time series study of daily deaths in Santiago was conducted by the World Bank team in collaboration with Chilean experts. Correcting for such confounding effects as weather and seasonality, estimated dose response functions for premature mortality were generally in line with those found elsewhere.

For Santiago, the basic, one-day model yielded a coefficient implying a central value of .6 percent (with a confidence interval of .4 to .7, shifting the coefficient up and down one standard deviation), when seasonality, temperature and other effects were accounted for. A three day moving average of PM-10 concentrations probably provided the best model, implying a central value of 1.1 percent per 10 micrograms/m^3 (confidence interval .9 to 1.35 percent, t-statistic of 4.4). Thus, indications are that the use of dose response functions from outside can be done with some confidence, even when countries are as different as the United States and Chile. Most likely, other developing country studies will now follow, as data and expertise is increasingly becoming available. In using PM-10 data, suspected by epidemiologist to be an improved measure of the health-threat, the Santiago study is an early contribution even in the light of industrialized countries.

In the Santiago data set, total deaths per day average 55 (all causes, less accidents), so a 1.1 percent reduction in mortality represents 221 deaths annually, with a confidence interval of 180 to 271. With a population of 4.7 million, this results in a central coefficient of 4.7 premature deaths per hundred thousand inhabitants for a 10 microgram/m^3 change in PM-10 (Table 3.8).

Additional insights can be gained by studying the effects by subcategories: For the total population, an increase in pollution of 115 micrograms/m^3 (the mean) raise the risks of death by eight percent for the total population (using the one-day model), but the increase is 11 percent for males and 6 percent for females, and 11 percent for those aged 65 and above. By diagnosis, the increase is 15 percent when the diagnosis is respiratory disease, and 9 percent when it is cardiovascular disease.

Another study, of lower respiratory illness among children, also produced results with close links to PM-10 concentrations. The study shows surprisingly consistent results across two data sets (clinics and an emergency room visits) and the results correspond well with results on respiratory symptoms from Los Angeles and Holland.

Sources: Ostro, Sanchez, Aranda, and Eskeland (1994), Ostro, Sanchez, Aranda, Eskeland, Angulo (1994).

3.42 Unfortunately, there is still uncertainty and controversy about much of the research on which these estimates are based. Recognizing this uncertainty, separate research has been initiated on dose response functions for various health endpoints in Santiago. Results from this research on premature mortality and respiratory clinic visits for children indicate effects similar to those found in the international literature (Box 3.1).

3.43 Thus, while this test is not a complete one, it provides some support for the supposition that dose response relationships do reflect some phenomena of susceptibility that are transferable from one city to another. Also, we shall be providing upper and lower bounds for the health effects, generally based on the ranges of uncertainty within and among the cited studies. Table 3.10 provides a summary of the applied dose response functions.

3.44 For the purpose of calculating health effects due to changes in ambient concentrations produced by the control scenario, it was conservatively assumed that health effects occur only for the improvements in air quality over and above ambient air quality standards. Estimates are not provided for other major air pollutants such as lead and carbon monoxide. For lead, ambient and blood levels should be coming down as unleaded gasoline increases its market share. Present data shows ambient lead levels higher in Santiago than in San Felipe, and 8 percent of 1 year olds have blood lead levels exceeding the guideline of 10 micrograms per deciliter[8]. Experience from the U.S. would indicate that ambient levels and blood lead levels will fall as lead use in gasoline falls. Inclusion of lead effects would add to the benefits of the gasoline strategy, but magnitudes have not been assessed. For CO, dose response functions are not well established.

3.45 Table 3.11 shows the estimated health effects for the four pollutants when implementing the control scenario. It may immediately be noted that most of the identified health effects estimated for the control scenario are associated with PM-10, or the respirable part of suspended particulates. This reflects a combination of phenomena: (i) dose response functions from the epidemiological literature have captured a broader range of health end-points (or symptoms) for this pollutant; (ii) PM-10 concentrations are high, violating the annual standard in all parts of the city most of the year; and (iii) the controls applied are quite effective in reducing emissions of PM-10.

3.46 For each of the dose response estimates, a range of uncertainty can be estimated on the basis of the standard deviation from the estimated dose response function (as indicated in Table 3.10). This question will be taken up after having introduced a common metric for health effects (work-day equivalents). For premature mortality,

8. We thank Jeannette Vega for providing this information, as well as for helpful discussions and introduction to Santiago material.

perhaps the most noteworthy of the health effects, confidence intervals indicated by one standard deviation would be plus and minus 22 percent for PM-10.

Table 3.10: Summary Table of Dose-Response Functions* for Santiago

	PM10 (per 10 $\mu g/m^3$)	SO_2 (per 10 $\mu g/m^3$)	Ozone (per pphm)	NO_2 (per pphm)
Premature Mortality/ 100,000	4.7 (3.9, 5.7)	3.3	.0055	
RHA/100,000	12.0 (6.57, 15.6)		7.70 (3.8, 12)	
ERV/100,000	234.4 (128.3, 342.5)			
RAD/Person	0.575 (.404, .903)			
LRI/Child	0.016 (.008, .023)			
Asthma Symptoms/Asthmatic	0.33 (.16, 2.73)		0.68 (.38, 1.90)	
Respiratory Symptoms/Person	1.83 (.91, 2.3)		0.55 (.28, .77)	
Chronic Bronchitis/100,000 > 25	44 (14.5, 61.7)			
MRAD/Person			.34 (.17, .51)	
Respiratory Symptoms/1,000 Children		0.18 (.1, .26)		
Chest discomfort		0.10 (.053, .15)		
Respiratory Symptom/Adult				0.10 (.06,.14)
Eye Irritations/Person			.266 (.234, .299)	

* Lower and higher case estimates in parenthesis (coefficients shifted one standard deviation).

3.47 A Common Metric for Health Effects. Reduction in air pollution is estimated to result in reductions in premature mortality as well as various symptoms of illness. To aggregate these into a common measure of health benefits, it is helpful to establish a value, or a unit cost, for each of the health effects in question.

Table 3.11: Health Effects, Central Case Estimates*, from Implementing Control Scenario

Reduction in ambient air pollution in locations exceeding standard	PM-10	Ozone	NO_2	SO_2
	8.43 $\mu g/m^3$	.0365 ppm	.013 ppm	.16 $\mu g/m^3$
Premature Mortality	186	1		3
Hospital Admissions	477	1,300		
Emergency Room Visits	9,351			
Restricted Activity Days	1,376,000			
Lower Respiratory Illness, Children	24,400			
Asthma Attacks	65,600	588,000		
Respiratory Symptoms	5,669,000	2,975,000	672,000	
Chronic Bronchitis •	1,116			
Minor Restr. in Activity		5,840,000		
Cough, Chest Discomfort				4,900
Eye irritations	4,951,000			

* For each health effect, the unit of measurement is the number of incidences.

3.48 The establishment of a consensus unit value for the prevention of premature mortality will necessarily be a task that is difficult conceptually as well as empirically. In the economic literature, one finds two approaches: the "human capital" approach and the "willingness to pay" approach. Willingness to pay approaches are more firmly grounded in theory, and consistent with the general framework of cost-benefit analysis under the most basic assumptions (costless transfers). The human capital approach, in contrast, does not have the same strong theoretical underpinnings. However, in valuing both mortality and illness by lost "productive" days (with the addition of treatment costs for illness), it is empirically very tractable, and provides measures that are easily communicated. Theoretical reasoning as well as empirical results from industrialized countries indicate that estimates based on human capital approaches and cost-of-illness approaches (both used here) are downwardly biased compared to the better-founded willingness to pay approaches. Thus, this study's valuation method probably contributes further to a downward bias in benefit estimation.

3.49 Since much of the effects of air pollution will result in days lost due to illness and death, we shall present much of the analysis using a quantitative measure, *work-day equivalents*, as a basis for cost-effectiveness analysis. This concept, then, will include treatment costs converted at average wages rates, so that the measure is in fact a monetary measure. Finally, we shall tentatively use average wage rates to value the work-day equivalents to complete a full comparison of control costs and health benefits using sensitivity analysis to assess the importance of the estimates of greatest uncertainty. Relevant estimates of willingness to pay for the kind of outcomes studied in this report do not exist, but would clearly represent a valuable input to this kind of analysis in future.

3.50 To approach the valuation of premature mortality, one may first ask: *How premature are these deaths*? The answer is of obvious relevance if one applies the human capital approach to valuation. However, the question should also be answered when a willingness to pay estimate is attempted[9]. Dose response functions for air pollution deaths are generally based on statistical relationships between deaths and ambient air pollution, but the results give little basis for estimating the number of life-years lost. As a first step, we have assumed that premature deaths due to air pollution show the same distribution by age as deaths due to pneumonia (from the scant physiological evidence and from age-specific dose response functions this appears to be a reasonable assumption), for which Santiago statistics from death certificates are available. Pneumonia deaths were 12.6 percent in the age group between 0 and 10 years, 28.2 percent in the age group between 10 and 64 years, and 59.2 percent in the 65+ category[10]. Secondly, we assume that the individuals dying prematurely due to air pollution would otherwise have an expected lifetime typical for their age group. This is definitely an estimate on the high side, since it is more likely that the individuals dying prematurely are in poorer health than average

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9. The applied economics literature generally fails to make this distinction, when the same values are applied across the board to programs irrespective of the number of life-years associated with each premature death saved. For instance, willingness to pay for risk-reduction may be estimated from wage-risk premia for healthy males. One may of course *choose* to see such estimates as uniformly applicable across life-saving programs, say for traffic deaths (which cost an average of 16 years each in the US) and heart disease deaths (which cost an average of 3-5 years in the US), but it is not self-evident that such a choice should be made.

10. Detailed background on these unit cost estimates are found in Sanchez, 1994.

for their age cohort. Using this methodology, we estimate that the average of premature deaths due to air pollution leads to a loss of 12.9 discounted productive years, or 4,709 days. Details of these calculations are shown in Table 3.12.

Table 3.12: Present Value*, by Time of Death

	Work-Years***	
	Women	Men
1 year old	8.4	6.7
42 years old	19.3	18.7
65 years old	12.4	11.8
Weighted Average**	12.9 work-years, or 45 thousand U.S. Dollars	

Source: Sanchez, WB calculations. * Discount rate is 5% (real). ** The weights (from tables of the National Statistics Institute) are 4.7, 5.3, 37.5 (women) and 6.6, 14.8, 31.1 (men). *** The figures are obtained by using sex and age-specific wage-schedules, then normalizing with one average wage so that one value applies uniformly to all deaths. The average annual wage is 3,482 dollars (Mideplan, Survey Casen 1990, adjusted).

3.51 Thus, a measure of the importance, or value, of reducing air-pollution related premature deaths may be that each results in 12.9 present work-year equivalents or 4,709 work-days. The figure reflects, as it should, that many who die prematurely from air pollution are 65 years or older (the higher number of deaths among elderly imply that these are weighted heavily in the average). However, some premature deaths are among younger individuals--indeed, some are among infants--each contributing to the *average* number of life-years lost per premature death even though the number of premature deaths among young is assumed to be comparatively low. One may also look at the dollar value suggested by average productivity, but we shall mostly concentrate on the work-day equivalents.

3.52 For morbidity, we shall use the concept of "cost of illness", quantifying the days lost in a fashion similar to that applied for premature mortality, but allowing for the possibility that the day's value is only partly lost (as with sore eyes) or that only part of the day is lost (as with minor restrictions of activity). We shall also include treatment costs, but will not include any valuation of pain and suffering. The data collected are from the public and private health systems in Chile[11]. Table 3.13 summarizes the unit cost estimates.

3.53 These unit cost estimates may be used as cost effectiveness measures, as one could compare the costs of saving a work-day equivalent across various public intervention programs, including different strategies for air pollution control. Further, they will be the basis of cost-benefit calculations and sensitivity analysis. For instance, one may change the value of treatment relative to days lost, or of days lost due to premature mortality versus days lost due to illness.

Table 3.13: Unit Cost Estimates for Health Effects
(in terms of work-day equivalents)

	Workdays Lost	Treatment Costs[1]	Total Costs	US Studies
Premature mortality	4,698	0	4,698	8-24,000
Resp. Hospital Adm.	9.32	43.6	53	225
Emergency room visits	1.28	2.2	3.47	2.06
Restricted activity days	.6	0	.6	.46
Lower resp. illness	8.34	11.7	20.1	2.61
Asthma attacks[a]	.4	.4	.8	
Respiratory symptoms[a]	.06	.06	.12	
Chronic Bronchitis	3,872	1,769	3,872	3,200
Minor Restr. in Activity[a]	.17	.17	.34	
Eye Irritation[a]	.06	.06	.12	
Cough, Chest	.06	.06	.12	

[a] For these health end-points, separate cost estimates for Chile have not been obtained, and values from U.S. studies have been converted, using the ratio of daily wages: 125/9.55. Further, for these symptoms, a 50/50 distribution over treatment costs and lost time is assumed.

[1] In Table 3.13, treatment costs are also reported in terms of work-day equivalents, using the average wage rate of 9.55 dollars per day.

11. When possible, these have been weighted by market share, and adjusted to obtain measures of full costs (Sanchez, 1994).

Table 3.14: Health Effect, Central Case Estimates, from implementing Control Scenario, thousand work-day equivalents

Exceedance Reduction in Ambient Pollution	PM-10 8.43 $\mu g/m^3$	Ozone .0365ppm	NO_2 .013 ppm	SO_2 .16 $\mu g/m^3$	Control Strategy
Premature Mortality	876	5		13	894
Hospital Admissions	25	69			94
Emergency Room Visits	33				33
Restricted Activity Days	820				820
Lower Respiratory Illness, Children	489				489
Asthma Attacks	52	470			522
Respiratory Symptoms	683	358	76		1,117
Chronic Bronchitis	4,321				4,321
Minor Restr. in Activity		1,987			1,987
Cough, Chest Discomfort				1	1
Eye irritations		550			550
Total for control strategy	7,299	3,440	76	14	10,829

3.54 As shown in Table 3.14, in terms of work-day-equivalents, the onset of chronic bronchitis is by far the most serious illness effect identified by the dose-response functions. It has been valued in a way similar to premature mortality: assuming an age-profile of the onset-dates similar to that of pneumonia deaths. Further, we have assumed, it causes a loss of a third of future days, in addition to treatment costs. The last column in Table 3.13 provides, for comparison, estimates from US studies. They are, mostly, based on willingness to pay estimates, and conversion has been made based on relative wages: 9.55 in Chile versus 125 in US. Clearly, were a conversion to be made at the foreign exchange rate, the US figures would be higher, though the comparison across different health effects would be the same.

3.55 Table 3.14 combines the unit cost estimates with the Central Case health effects in the Control Scenario from Table 3.13 in terms of work-day equivalents. Using this metric, PM-10 provides most of the health benefits from the control strategy. For the Control Strategy, which - in percentage terms - is more successful in reducing ozone than it is in reducing particles, PM-10 exceedance reductions provide almost twice the health benefits that are provided by the ozone exceedance reductions. The benefits provided by NOx and SOx reductions are small in comparison.

F. Cost-Benefit Analysis: Conclusions and Recommendations

3.56 Applying a value of US$9.55 to an average work-day in Chile, the health effects associated with the reductions in PM-10, NO_2 and Ozone concentrations are estimated to generate annual health benefits in the range of US$100 million, comparing favorably with control costs in the range of US$60 million. Table 3.15 shows benefits by pollutant (US$18,192/t PM-10, US$1,390/t NOx, and US$495/t VOC). The table's results provide rather general guidelines. Thus, a wider range of control initiatives may be tested: a lower bound for the benefits they generate is estimated by using the benefits per ton for each pollutant in Table 3.15, so that a complete rerun of the analysis and modelling of this paper is not necessary. A disaggregation of control strategies could show some of these more attractive than others, thereby assisting in strategy choice.

Table 3.15: Benefits by Pollutant

Ambient Pollutant	Benefit (Mn$)	Emitted Pollutant	Tons Reduced	Benefits/ton
PM-10	69.71	PM-10	3,831	18,192
Ozone	32.85	VOC	33,167	495*
		NOx	12,336	1,315*
NOx	0.726	NOx	12,336	59
		NOx Total	12,336	1,390*
SOx	.134	SOx	1,639	82

* Calculated assuming NOx and VOC contributes equally to ozone generation. The prioritization between VOC and NOx is sensitive to this assumption, but the prioritization between strategies in the *Control Strategy* is not.

3.57 Table 3.16 shows a prioritization by program component. Benefits exceed costs for all component strategies. For the gasoline strategy, which is quite expensive if evaluated solely on the basis of particulate reductions, benefits associated with ozone reductions make the strategy quite attractive. Since the gasoline vehicle strategy is intense in both VOC and NOX, its benefit-cost ratio is not very sensitive to the assumption about which of the two pollutants contributes more to ambient ozone concentration, though it is sensitive to the total reductions. We should take note, also, that the associated lead reductions are not given credit, so there are good reasons to believe a specific downward bias relates to the benefits (and thus the benefit/cost ratio) of the gasoline strategy. For the bus strategy, it is likely that costs are estimated on the high side, since the conversions are not credited with any fuel cost savings. Depending on what it will cost to get natural gas in Santiago, CNG conversion of buses (and, perhaps, other sources) might be more attractive than the estimates suggest.[12]

Table 3.16: Benefits and Costs by Program Component (US$ million)

	Benefits*	Costs	B/C Ratio
Fixed Sources	27	11	2.4
Gasoline Vehicles	33	14	2.4
Buses	37	30	1.2
Trucks	8	4	1.8
Control Strategy	103	60	1.7

* Calculated assuming VOC and NOx have equal roles as ozone precursors. The Benefit/Cost ratio of the gasoline vehicle program, which is most intense in the precursors, is not very sensitive to this assumption.

3.58 The general attractiveness of the control strategy that is shown in these calculations does not appear to be sensitive to the uncertainty involved. Only two benefit estimates are not conservatively assessed. One is the number of years lost associated with each premature death. However, premature mortality represents only about 10 percent of total benefits, so a more conservatively estimated number of life years lost would not change the conclusion that the control strategy is attractive. The other estimate that may not be conservatively assessed is the unit cost of chronic bronchitis. This health effect represents 38 percent of the health effects, and could be halved without changing the favorable ratio of benefits to costs.

12. Some research exists on particle composition and its mutagenicity/carcinogenicity. This research has indicated that combustion sources, and diesel vehicles among these, contribute to the nastiest parts of ambient PM-10. The particles have properties that are likely to have adverse health effects, including some (such as cancer) that would not be identifiable in short term studies - the basis of the dose response functions behind this study's benefit estimates.

3.59 In general, however, the principle has been followed to assess benefits conservatively. A threshold effect is assumed, in practice limiting the benefits associated with VOC control and NOx controls, as a precursor to Ozone, and also limiting the health effects associated with the health damage from SOx. This assumption generally has a conservative effect. For PM-10, since concentrations are above the threshold values across the city, the assumption has no practical implications.

3.60 The confidence intervals due to the difficult issue of quantifying and valuing days lost because of premature mortality may to some extent be narrowed through further research - such values may be more critical at a later stage in the process, when the air quality is better and the remaining control options are costlier. The variance in estimated dose response functions will not be removed, though our research has brought us closer to an answer on how applicable these are to Santiago.

Analysis as a support for policy discussion and decisions

3.61 Public sentiment as well as policy already reflect willingness to undertake control measures to reduce air pollution in Santiago. The present analysis indicates that pollution control measures may be justified, in a cost-benefit analysis, on the basis of health benefits alone. Thus, were the population of Santiago to be charged for the health benefits they would experience, the collected revenues would be sufficient to finance the measures for air pollution reduction.

3.62 This result, while relevant, is an abstraction -- pollution reduction policies are more efficient if polluters are asked to pay than if those who reduce emissions are compensated for their costs by the beneficiaries. Our analysis provides first estimates on a number of parameters a policy-maker would need to change the incentives of polluters. While *some* measures, in tentative calculations like these, may provide net benefits, policies should be designed to induce the adoption of such (and only such) measures as will provide benefits in excess of control costs. Whenever possible, such incentives should be general enough to allow polluters flexibility to choose how to reduce emissions.

3.63 The most important contribution of this analysis will be to provide inputs on parameters for which the public "pollution manager" has to provide the answers. Such parameters are the relative priorities of pollutants (Table 3.15), the premium for downtown emitters (Table 3.8), and the benefits to the public of emission reductions.

3.64 In practice, the policy maker will probably also perform more detailed analysis, such as how much to demand from the transportation sector, as opposed to from industries and residences. Clearly, results from this analysis are relevant for such decisions. It should be recognized, however, that such decisions should preferably be left to the market, though they do require careful implementation design. Thus, while assistance from market forces should be sought, carefully designed interventions are required to mobilize these.

3.65 For more detailed evaluations, however, such as the question of the most cost-effective solution for old diesel buses, our analysis should only be taken as showing that solutions exist that would be worthwhile pursuing. Flexible instruments, such as presumptive charges based on annual testing, utilization rates *and* the pollutant priority weights that our analysis yields could then be used to induce emission reductions from buses. Under flexible instruments, bus operators would face the challenge of finding more effective emission control measures if possible. Entrepreneurs would then, in the second round, be challenged to convince bus operators and industrial firms that they have cost effective solutions for them, be they new vehicles, conversion kits, cleaner fuels, or combinations. Local and national government institutions, moving first and last, face the challenge of making sure that the efforts made by polluters in order to avoid paying emission taxes (or to comply with permits) produce genuine emission reductions.

3.66 For parts of the uncertainty and heterogeneity affecting air pollution control analysis, policy instruments may be designed to allow polluters the optimal flexibility, so that they reveal information and exploit eventual control cost advantages that individual polluters might have. One such mechanism, proposed in Chile, is a compensation system for PM-10 from fixed point sources. It has long been known that such systems can be cost-effective; however, they must be designed to deal with two important problems. One is the problem of initial allocations: there are indications that the proposed initial permit allocations will allow too much "head-room", so that emissions may increase once trades are allowed (if "head-room" in initial allocations is high, permits that are bought may be sold from someone that would not have used them to someone who will use them, increasing total emissions). Another problem concerns dispersion: PM-10 concentrations are worse in central areas, and the program should either prevent trades from the periphery to the center, or apply a premium reflecting the higher damages from centrally located sources. Our analysis provides the inputs for solving such problems, such as the appropriate "downtown" premium. If these problems are poorly addressed, so that emission reductions do not result, the public will dislike the program. The fact that the program has saved costs *and could* have reduced emissions, had it been better designed, will mobilize little appreciation.

Policy Recommendations

3.67 The present study also gives concrete directions on specific policy questions: On an emitted ton basis, PM-10 reductions are more than 10 times as valuable, in terms of health benefits, as any of the other pollutants. The reduction of one ton of PM-10 emissions from each broad group of emitters, such as fixed sources, buses, cars and trucks, has about the same effect in terms of reducing PM-10 exposure. Thus, in an efficient pollution control strategy, the marginal control costs per ton of emission reduction should be roughly equal across these groups of emitters. Several analyzed strategies for reducing PM-10 emissions are economically attractive and yield benefits in the order of 1.2 to 2.4 times the control costs (including diesel truck emission standards, conversion of buses to natural gas, and conversion of wood burning industries to oil or gas).

3.68 The analyzed PM-10 emission controls produce about US$70 million in health benefits, equivalent to US$9 million per $\mu g/m^3$ reduction, or US$18,000 per emitted ton reduced. Thus, controls reducing PM-10 emissions at costs below US$18,000 per ton should be considered worth-while.[13] US$18,000 per ton of PM-10 emission can also be seen as a reasonable threshold value for evaluating policies stimulating emission controls, such as general or more directed charges backed by monitoring efforts (also for the calculation of tradeoffs in industry licensing, fuel and energy pricing, licensing of buses for Santiago, equipment standards). If emission taxes can be levied, US$18,000 per ton would be giving appropriate incentives to emission reductions (based on conservative estimates). Again, as with the compensation system, a down-town premium could be applied, further improving the effectiveness of the incentives.

3.69 The PM-10 compensation mechanism for fixed sources faces important challenges: initial endowments need to be both tight and firm (i.e., not subject to manipulation), for emissions not to increase, let alone decrease. Further, a two-zone arrangement should be evaluated to give sufficient priority to central areas.

3.70 General energy price increases (implemented, for example, through energy taxes), as well as increased user charges for wood-fuel and electricity (for the latter, assuming that coal is used extensively at the margin, and that coal-fired power plants are not tightly controlled) are simple approaches that can deliver PM-10 emission reductions without much institutional change, monitoring and enforcement.

3.71 Even though the costs of gasoline vehicle emission controls are high per ton of reduced PM-10 emission, additional gains in ozone reduction make such controls attractive (benefit-cost ratio of 2.4). The control scenario leads to a reduction in health damage from ozone of US$32 million. The benefit-cost calculations for ozone are more uncertain, since the relative importance of the precursors, hydrocarbons and nitrogen oxides, is not known. As the gasoline vehicle measures are being implemented, total emissions of VOC and NOx will be reduced by 65 and 30 percent, respectively, and a

13. This figure was calculated for current pollution levels. However, for PM-10, the control scenario removes only a small fraction of emissions (15 percent), and ambient concentrations would remain high. The dispersion, exposure and health effect models are all quite linear in this range, so the value estimate of US$18,000 can also be used to evaluate emission reductions beyond the analyzed control scenario.

greater share of the city will be in compliance with the standard, resulting in lower benefits from any additional future measures for the reduction of ozone pollution.

3.72 Additional research and analysis is needed on the behavior of entrained dust, and on control strategies for dust. With present knowledge, it would be reasonable to presume that benefits from road dust emission reductions are somewhat lower than the estimated US$18,000 per emitted ton for dust from other sources, due to a lower impact on concentrations and exposure, and due to a less harmful size and chemical composition. However, road dust could still represent quantitatively important and cost-effective control opportunities, as one can likely find control strategies that are of low cost on an emitted ton basis. Once measures of the health benefits of road paving have been developed, these should be included in the evaluation of transportation sector projects (such as road paving), especially in heavily populated areas.

3.73 More research should be undertaken on other forms of air pollution, and on the population at risk. The analysis should comprise other pollutants of health importance, e.g. lead, and include indoor and occupational exposure and other factors that are prone to be predisposing factors of respiratory ailments. Extending ongoing research on particle composition and its mutagenicity/carcinogenicity can contribute to the effectiveness of the efforts to deliver public health improvements in Santiago and elsewhere.

IV. NATIVE FORESTS MANAGEMENT OPTIONS IN SOUTHERN CHILE: ASSESSING TRADEOFFS BETWEEN INCOME AND BIODIVERSITY[1]

A. Background

4.1 Chile is facing a major resource management dilemma: how to manage the extensive areas under native forests while still allowing the growth of the dynamic commercial timber sector, largely built upon fast-growing exotic species. The preservation and improved management of Chile's native forests is a topic that is receiving intense public attention and is debated in the press, in the National Congress, and in academic and research fora. The primary issue is the tradeoff between the economic and ecological benefits of conserving and managing intact native forests as compared to the financial returns from clearcutting and/or conversion of native forests to exotic species plantations, or conversion to non-forestry uses. The main incentive is the high value of standing timber. Recreation and tourism, important industries in many forested areas, offer an opportunity for economic gain while leaving forests relatively intact.

4.2 Although estimates vary considerably, Chile is believed to have about 33.8 million ha (MH) of land suitable for forestry (tierras de aptitud preferentemente forestal, TAPF), or about 45% of the total area of the country. Of this, about 9 MH are "potentially productive forests" of which native forests cover an estimated 7.6 MH, the rest being under plantations of Radiata pine and eucalyptus. Another 13.8 MH are under various categories of protected status.[2] A major share of the potentially productive forests is concentrated in the 10th Region (the Lakes Region), roughly between 39 and 42 degrees latitude (CODEFF 1992). Of Chile's potentially productive native forests, the 10th Region is estimated to contain 48% of the total by area and fully 80% of the entire 940 million cubic meters of volume of potentially productive forests (INFOR 1992).

4.3 The extensive development of plantations of exotic species, largely Radiata pine (<u>pinus radiata</u>) and eucalyptus, are seen as threatening Chile's native forests. Whereas exotic species plantations record growth rates of 20 m^3/ha/yr or more, native species grow at a much slower rate, estimated at between 4 and 10 m^3/ha/yr, with a few species growing at slightly faster rates. Plantations presently cover over 1.6 million ha

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1. This chapter was written by John A. Dixon drawing heavily on specially commissioned papers by Gonzalo Paredes and Claudio Donoso, both of the Universidad Austral, Valdivia, and Monica Rios of ILADES, Santiago. References to these background papers are given at the end of the report.

2. The main categories of protected areas are National Parks (8.4 MH), National Reserves (5.5 MH), and Natural Monuments (less than 0.02 MH). (CODEFF, 1992).

in Chile, 90% under Radiata pine, with eucalyptus becoming increasingly popular (CORMA 1992). Of the area under plantations, as little as 5% to 10% are thought to be planted on lands that were covered by native forests. The rest are established on lands that were under agricultural use or on previously cleared, degraded forest areas.

4.4 Forestry is big business in Chile; the sector accounted for about 3.3% of GDP in 1992 and has had an annual growth rate of about 5% per year over the past 15 years. Exports of chips, pulp and paper, and wood have exceeded US$1.2 billion in 1993. Forestry products account for about 10% of total exports and vie with fruit products for second place after copper. In recent years the expansion of plantation forestry has been in the south of Chile, centered in the 7th to 10th regions, the latter being a region with an extensive area under native forests. At the same time chip exports have grown rapidly, largely based on native forest species. As new plantations are proposed, and as chip production expands, the issue of conservation or conversion of native forests has taken on increased immediacy.

B. Protection or Conversion?

4.5 Until three decades ago, the forest sector was largely based upon the use of native forests. The National Forestry Corporation, CONAF, was established in 1972. With passage of DL 701, the Ley de Fomento Forestal (the Forestry Development Law) in 1974, incentives were introduced for afforestation with exotic and native species, and assurances were given about the security of land tenure; CONAF helped implement and manage activities under DL 701. Ten years later, in 1984, the National System of Protected Areas, SNASPE, was created and was placed within CONAF. The rapid introduction of industrial plantations based upon exotic species followed the passage of DL 701; the forestry industry is now divided between a highly developed commercial sector, and a rather primitive, underdeveloped sector based on the management and exploitation of native forests.

4.6 As a result of the success of the industrial plantation sector, native forests are under increasing pressure for conversion to alternative uses. At the same time, there is growing concern about protecting Chile's remaining native forest resources. Various reasons are given for the protection of native forests including the potential for increased production of high valued wood products, biodiversity benefits, tourism and recreational values, watershed protection, habitat for flora and fauna, aesthetic benefits, and the importance of maintaining representative examples of Chile's native forest heritage. Although forests are also lost to agricultural and urban uses, plantation forestry and chipping are seen as the major threats to native forests.

4.7 Economic forces are the principal driving factor behind the conversion and/or destruction of areas under native forests. Many owners of native forests believe them to be low-value, difficult to manage resources and see chipping and/or plantation forestry as options that produce greater economic benefits. (More recently, the price crisis in the agricultural sector has led farmers to convert low-productivity crop lands to intensive industrial forestry, mostly with eucalyptus. In 1991, 50,000 ha of lands classified for agriculture were replanted in forests. This process is called "reconversion agricola" and is common in the 7th to 10th regions.) Legislation presently under consideration would prohibit or severely restrict clearing and/or interplanting with exotic species. In addition, an often overlooked dimension is the pervasive degradation of native forests by small land owners -- either for firewood extraction (leña) or conversion to agricultural lands. In fact, one frequently observes a cycle of degradation proceeding from firewood extraction, to agricultural production, and finally to grasslands and livestock. Unclear property rights, especially in the more southern portions of the 10th region, reinforces this tendency. (Another cause of forest degradation are forest fires, particularly in Regions V, VI, VII and the SMR. During 1990-93, Chile lost on average 43,000 ha. per year due to fire.)

4.8 There are also concerns about the sustainability of single-species forest plantations and their long-term impact on soils and sustainable forestry production. Certain diseases and insect problems of Radiata pine have already appeared in some areas (e.g. the polilla del brote, Rhyacionia buoliana), and both public and private research centers are actively working on pest and disease problems for Radiata pine and eucalyptus.

4.9 The debate on native forest management has become highly emotional, and, since a draft native forest management law was passed by the Camara de Diputados (the House of the Chilean Congress) in January, 1994, and is still working its way through the Congress, the debate is likely to continue. Major issues in the discussion include the level of management subsidies, and restrictions on conversion of native forests to other forestry systems. To answer some of these questions, a study was carried out to assess the management of native forests in southern Chile, and the various options available to meet differing, and sometimes conflicting, goals.

C. Study Design and Methodology

4.10 The study, carried out in an economic and land allocation framework, compares the benefits of native forests under present and proposed management regimes with the expected returns from alternative management scenarios, including conversion to other forestry systems (e.g. mixed forests or exotic species plantations) and non-forestry uses. A number of forestry management alternatives have been identified, ranging from improved management of native forests, through management of mixed forests of native and exotic (non-native) species, to the introduction of plantations of exotic species. National biodiversity and protected areas goals are also examined within the context of management options for native forests.

4.11 Representative native and exotic forest systems were selected for detailed analysis of the alternative management options. For each alternative the economic analysis was based on information on the productivity and sustainability of the system, realizing that there is considerable controversy over the extent of available scientific information on native forest management and expected outputs under different management scenarios.

4.12 The focus of the study is a transect of the southern part of the province of Valdivia and the northern part of the province of Osorno in the 10th Region, a slice roughly 180 km wide and 80 km deep (see Figure 4.1). The study area, therefore, includes about 20% of the 72,600 km^2 contained in the 10th region, and contains, based on the GIS maps developed for the study, about 335,000 ha of forest lands. (Forests lands account for about a quarter of the total land area in the transect, the remainder being agricultural lands, open area, wetlands, lakes, settlements, and non-forested areas of the Andes.)

4.13 The transect contains all of the most typical types of ownership patterns: large farms, often containing thousands of hectares, owned by individuals or large corporations (such as Terranova, a CAP company), small forestry land holdings, small agricultural land holdings with some coverage of native forests, small to medium sized farms owned by entrepreneurs in recreational/scenic areas by the Andean lakes, and large farms under native forests located in the Andes (see Figure 4.2).[3] Large forestry farms (over 5000 ha) dominate in the Cordillera de la Costa and in the Andes, while small farms (from 20 to 100 ha) are found along the river valleys. In the Central Valley medium-sized farms are largely engaged in agriculture and livestock production, but there are growing economic forces encouraging the conversion of land to short-term industrial plantations or selling it outright to large industrial forestry operations. More information is needed on the patterns of forest land ownership in the transect area and in the 10th Region more generally.

4.14 The transect also includes areas under SNASPE (the National System of Protected Areas) such as the 2,308 ha Alerce Costero Natural Monument and the Valdivia National Reserve (9,727 ha), both located in the Coastal Range (see Figure 4.1). Within the transect there are also areas that could be potentially incorporated into SNASPE because of their biodiversity or scenic values.

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3. It is interesting to note that significant human alteration to the landscape began in the middle of the 19th century with German settlement in the area. The central valleys were cleared for agriculture, and, as more settlers arrived, they placed increased pressure on the forests lands of both the Coastal and Andean ranges.

FIGURE 4.1:
STUDY TRANSECT AND PROTECTED AREAS
IN REGIONS 7 THROUGH 10

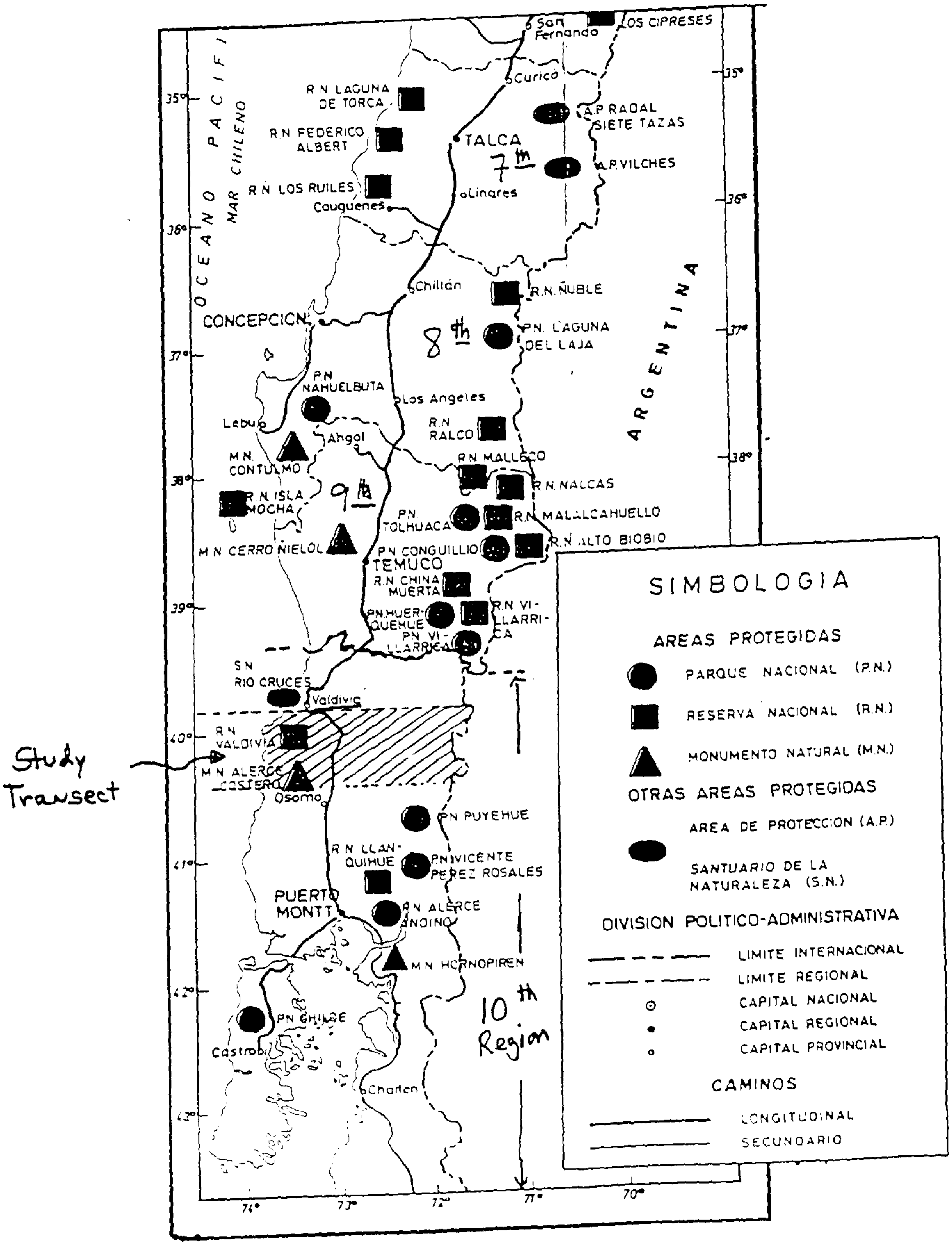
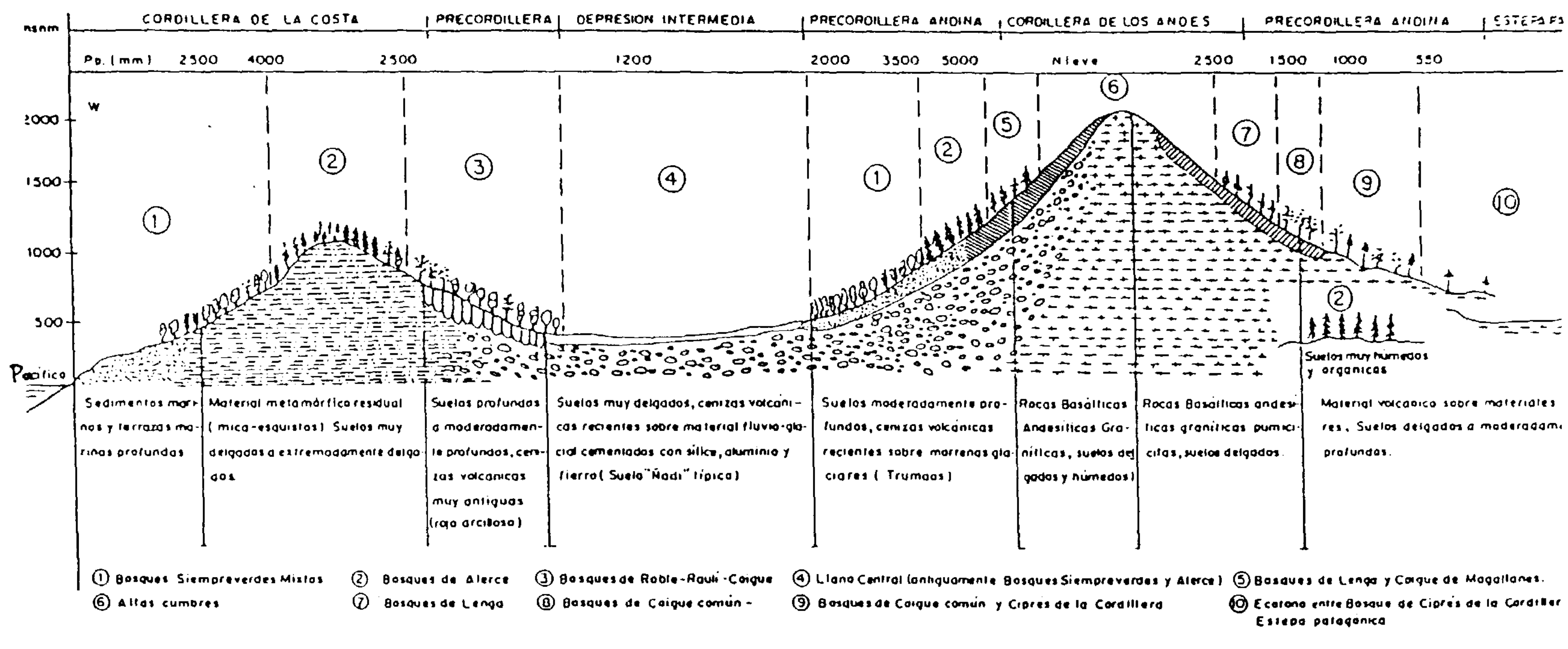


FIGURE 4.2: TRANSECT FOR THE NATIVE FOREST MANAGEMENT STUDY



4.15 Soils in the transect reflect the volcanic history of the region and the results of erosion and sedimentation. The soils of the Coastal Range tend to be thin; in contrast, the Andes are characterized by deep soils of volcanic origin. Precipitation is substantial, ranging from 2,-4000 mm per year in parts of the Coastal Range, to 3-5000 mm in the Andes. Parts of the Central Valley are drier, being located in the "rain shadow" of the Coastal Range. The soils and precipitation in the transect combine to make the area an important forestry region, characterized by rapid growth and an abundance of species and microclimates.

4.16 With the extensive development of plantation forestry in the regions to the north, the study area is also at the "frontier" in terms of plantation forestry development.[4] It is an area where new plantations of Eucalyptus and Radiata pine are being developed in areas currently covered with degraded native forests or devoted to agricultural activities, notably in the Coastal Range and in some parts of the Central Valley. As such, the study transect offers examples of all the major management issues being faced by resource planners in Chile.

D. Main Forest Types in the Study Area

4.17 The study transect contains representative samples of most native forest types in the Region and Figure 4.3 shows the location of the different forests types. As seen in Table 4.1 the most common forest types in the transect are the Coigue-Rauli-Tepa, the evergreen, or Siempreverde, and the Lenga forests. Table 4.1 also shows that almost half of the total forest area in the transect had harvesting constraints due to slope or soil type.

4.18 The Coigue-Rauli-Tepa, mixed evergreen, forests, Co-Ra-Te, cover 168,000 ha and are primarily located in the Cordillera de los Andes, starting behind the Andean lakes and extending to the frontier with Argentina. This forest type grows between 550 and 1000 m above sea level and receives 1550 to 4000 mm of precipitation annually.

4.19 The Siempreverde, mixed evergreen, forest type is second in coverage in the transect (about 82,000 ha) and is part of the most extensive and complex forest type in Chile. In the study transect it is largely found in the Coastal range and in selected areas in the pre-Andes and the Andes. A number of sub-types have been identified depending on dominant species; Siempreverde forests grow in areas from 0 to 1000 m above sea level, and in areas with high precipitation (2,-5,000 mm).

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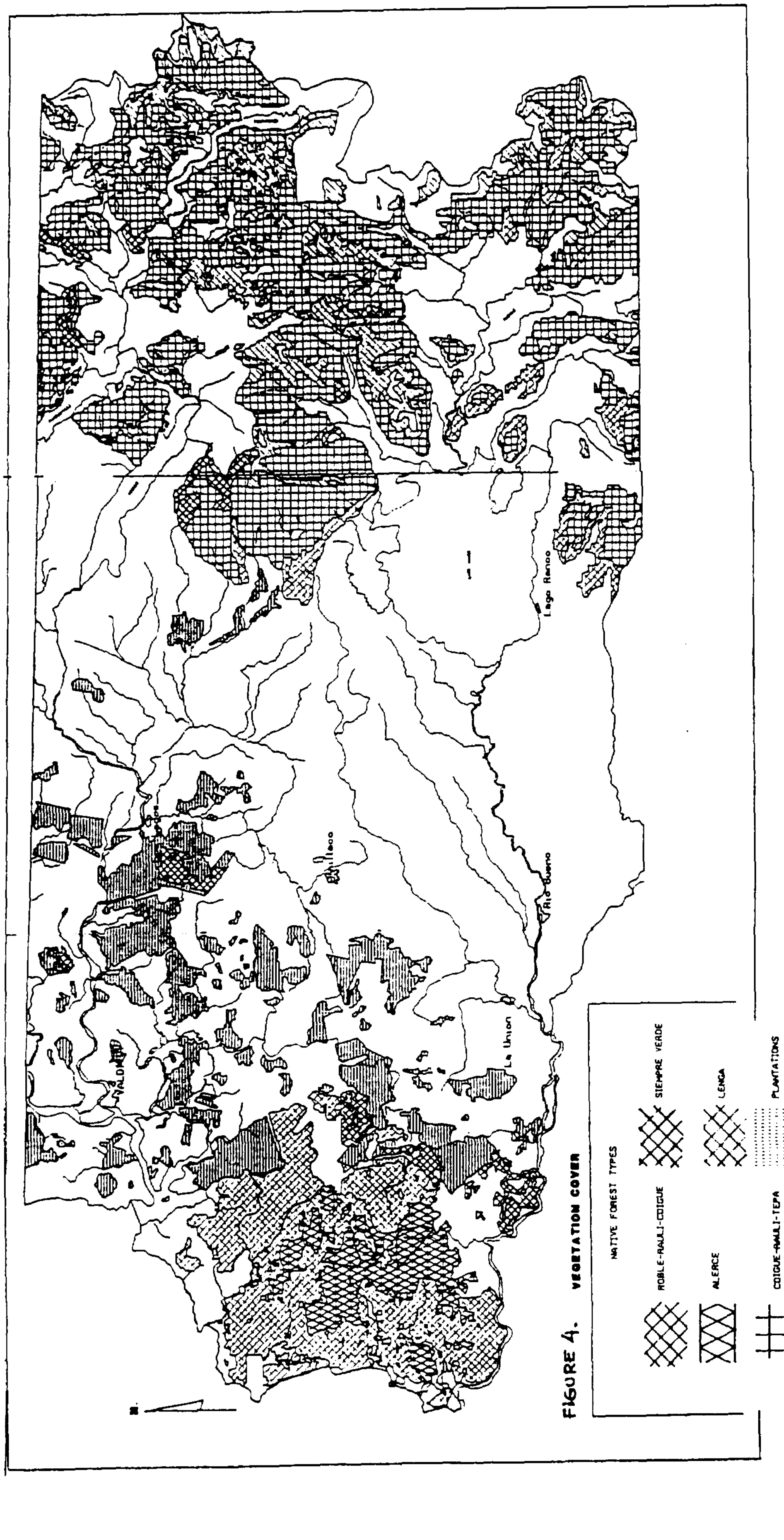
4. The 10th Region accounts for no more than 8% of the total plantings of Radiata pine in Chile, and about 10% of the plantings of eucalyptus.

FIGURE 4.3: VEGETATION COVER



4.20 The Roble-Rauli-Coigue forests, Ro-Ra-Co, cover 16,000 ha and are under intensive pressure from conversion to agricultural uses. Growing between 100 to 600 m, they are largely found in the Central Valley and in the foothills of both the Coastal and Andean range. In contrast, Lenga forests cover 46,000 ha and are largely found at higher elevations in the Andean range and are protected by their poor accessibility. Similarly, the Alerce forests (22,000 ha) are found in the Coastal Range and are all protected -- only dead trees may be harvested, leading to a marked increase in "mortality" in the remaining stands.

Table 4.1: Forest type, and lands with soil constraints in the study transect

Forest Type	Forests with soil constraint (hectares)	Total Area (hectares)
Alerce	2,908	22,028
Siempreverde, SV (evergreen)	26,980	82,152
Co-Ra-Te	90,980	168,028
Ro-Ra-Co	5,836	16,296
Lenga	26,936	45,940
TOTAL	153,640	334,444

E. Forestry Production in the Region

4.21 According to a recent study of the Instituto Forestal (INFOR, 1992), the 10th Region produces about 4.7 million m^3 yearly of native forest species and only 0.6 million m^3 from industrial plantations, largely Radiata pine (many plantations in the Region have been established relatively recently and are not yet producing harvests.) Firewood (leña) is the major market for native species -- fully 76% of the annual harvest (roughly 3.6 million m^3) is used for firewood, the major heating source in the Region and much of the South.[5] Much smaller shares go to other uses: chips (10.8%), sawmills (9%), particleboard (4%), and export of logs (0.2%). Firewood is collected in the more

5. CODEFF, a leading environmental NGO, estimates that for Chile about 146,000 ha. of forest land are exploited for firewood extraction each year, totalling about 7.3 million m^3 in 1992. CORMA, a forestry industry group, estimated 1989 firewood production at about 5 million m^3.

accessible areas, and is often from small forest holdings. Firewood collection often leads to the gradual degradation of forest areas, one truck load at a time. As the chip market expands, questions are increasingly asked about the largely unregulated firewood market, and its relative impact compared to the heavily monitored chipping industry. There is significant concern, however, about illegal native forest cutting by smallholders for delivery to chipping factories.

4.22 Since commercial industrial forestry plantings are only gradually coming on line, their share of the region's total forestry production is likely to increase rapidly in the future. According to the Forestry Institute, INFOR, the 10th Region had about 110,000 ha of exotic species plantations in 1991 (87% Radiata pine), and new plantings were taking place at a rate of about 15,000 ha per year, with eucalyptus accounting for about one third of this amount. Between 80-90% of all plantation lands in the Region are located in the Province of Valdivia, which basically covers the same area as the study transect.

4.23 Harvesting rates are a function of the species planted and their age distribution. Currently only about 400 - 1000 ha of plantation forest are cut each year, corresponding to forests planted during the 1975-77 period. As the large plantings of the past two decades mature, however, harvests rates will quickly increase to 4,000 to 5,000 ha per year, and eventually the annual harvest rate may stabilize at around 10,000 to 15,000 ha per year, the current planting rate. As a result of these forces, the share of the total forest harvest coming from plantations will increase, and in the longer run there may be decreased pressure to produce chips, wood, or firewood from native forests. The nature of these pressures will depend on the internal and external markets, the accessibility of remaining native forest areas, and the economics of areas further south.

4.24 With the exception of Alerce and Araucaria, whose harvest is prohibited by law (unless they are "dead" trees), different harvesting regimes are permitted under DL 701 regulations.[6] For each forest type the permitted options depend on a number of variables including slope and soil characteristics, and the dominant tree species found in the area. In the study transect the major management options are listed in Table 4.2; these options include clearcutting, protection, selection, and thinning. Each harvesting regime is described in turn.

4.25 Under the clearcutting harvest method (also known as the seed-tree method), all basal area is removed and a minimum of 10 trees per ha are left to allow

6. The case of Alerce is interesting; since harvesting of Alerce is completely prohibited except for the removal of dead trees, land owners have no incentive to prevent the causes of pre-mature mortality of Alerce, such as forest fires. This simple fact explains why there still remains an important processing sector based on the use of Alerce wood.

natural regeneration of the forest. Clearcutting is not permitted on slopes greater that 45%.

4.26 In the protection method (also known as the shelterwood method) 30 to 40% of the basal area is left standing to ensure regeneration. This system requires silvicultural investment for 3 years to ensure successful regeneration after the initial thinning, and management is based on a 30 to 40 year rotation. Both clearcutting and the protection system are designed to produce an even-aged stand. In a variation of this used in evergreen forests, clear cut rows are created, each row measuring 20 to 50 meters or more wide. The economic incentive for private property owners is to increase the width of each row, thereby harvesting more trees in the initial harvest.

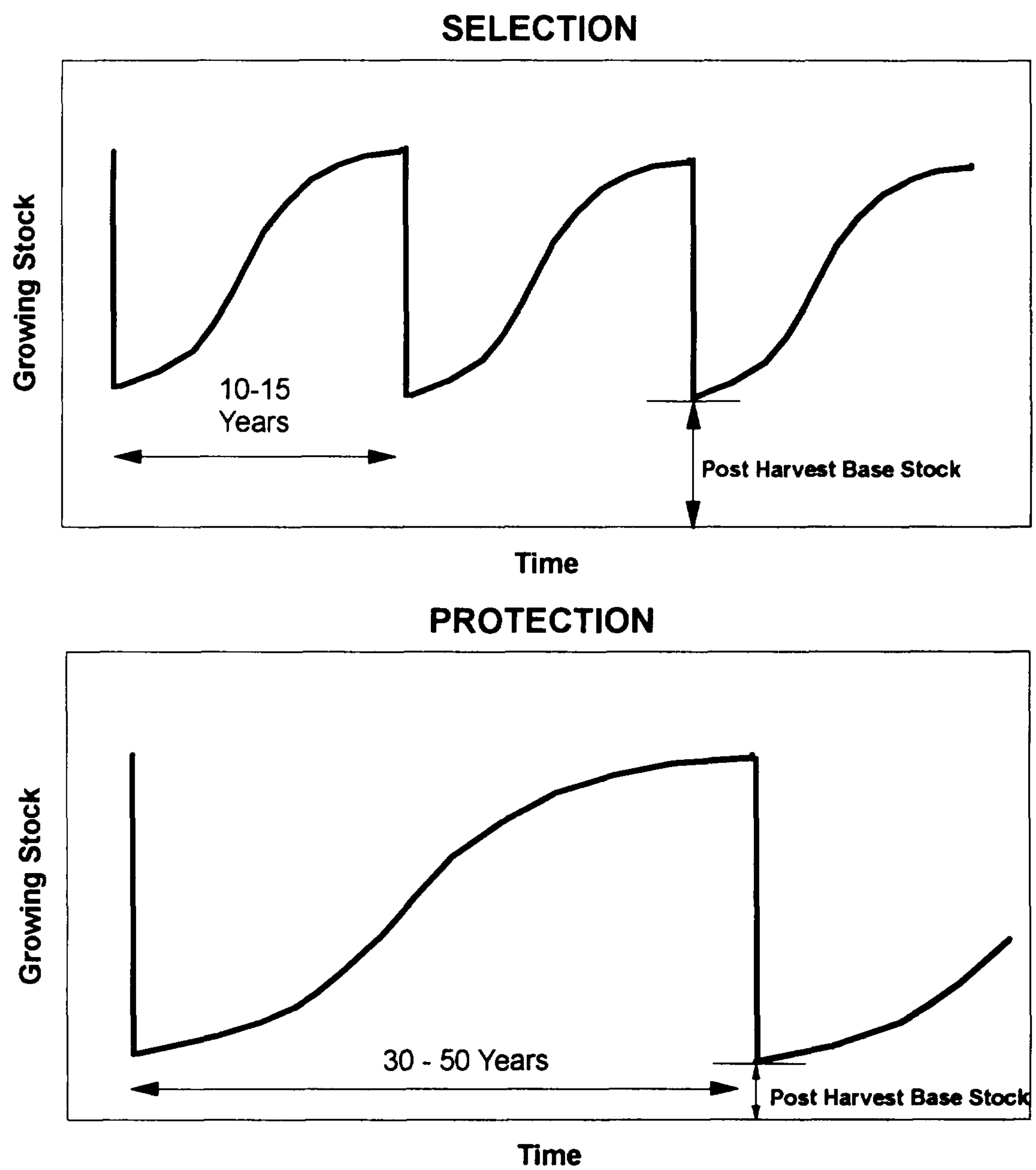
4.27 In contrast to clearcutting and protection, the selection method is used to maintain an uneven-aged forest, similar in structure to the original native forest. The initial harvest is designed to adjust the age and diameter structure of the stand and about 50-60% of the basal area is left standing as growing stock with subsequent harvests of 10-15% of the standing volume every 10 years. In each cutting cycle only a selection of the larger trees is harvested, thereby leaving a tree-diameter structure with high growth potential. Since trees are selectively harvested more frequently, the cutting cycle is much shorter and harvest volumes are smaller than with other management regimes.

4.28 In sum, the clearcutting, seed-tree, protection, and shelterwood systems create homogenous even-aged stands, while the selection harvesting system maintains a mixed, uneven aged forest structure. Figure 4.4 illustrates the differences between the selection and protection system in terms of initial harvest, growing stock and timing of subsequent harvests. In comparison to the protection system, the selection system leaves a considerably larger volume of growing stock after the first harvest and has more frequent subsequent harvests.

Table 4.2: Potential Management Options for Different Forest Types

Forest type	Subtype	Clearcutting	Protection	Selection	Thinning
Siempre-verde, SV	Olivillo		X	X	
	SV		X	X	
	Canelo				X
	Nadis		X	X	
Roble-Rauli-Coigue, Ro-Ra-Co	Altered	X	X	X	
	Original	X	X	X	
	Regrowth	X			X
Coigue-Rauli-Tepa, Co-Ra-Te	Adult forest		X	X	
	Regrowth				X

FIGURE 4.4:
SELECTION AND PROTECTION MANAGEMENT REGIMES
FIRST HARVEST AND VOLUME VARIATIONS OVER TIME



4.29 A final management option is the complete removal of the native forest, called conversion. In this case clearcutting is followed by planting with another (usually exotic) species or by conversion to agricultural use. The conversion option is allowed under DL 701 only if CONAF accepts the plan and certifies that there is no risk of erosion. Conversion sparked much of the forestry debate in the late 1980s, especially since some owners claimed that their lands were "degraded" and not, therefore, manageable as native forests. Owners can then obtain permission to practice conversion, often by clearcutting for chips and then replanting with native or exotic species. In practice, although prohibited by the approved management plan, owners sometimes abandon the land after the initial harvest.

4.30 Land can be declared "degraded" for a number of different reasons. These commonly include lands that have a combination of species with low commercial stumpage values. In other cases useful forest species have been replaced by shrubs or other species that prevents the regeneration of more desirable species.

4.31 Whatever the situation, land owners with native forest species consider a number of management and development options in order to select that option that produces the greatest expected financial benefit. With the restrictions on native forests that are currently in place, the result is frequently management plans that are sub-optimal from both an economic and an ecological perspective. These contradictions are explored in the next section.

F. Economic Analysis of Forestry Management Options

4.32 Although much of the discussion of management options for native forests has focused on the expected financial returns from both native forests and industrial plantation systems, other indirect benefits and costs of management decisions also have to be considered. These include important biodiversity benefits from protecting intact native forests, and the rapidly growing tourism/recreation industry. The economic analysis should determine if the total benefits of any alternative exceed the total costs, when environmental, biodiversity and recreational values are included in both the benefit and cost side.

4.33 The economic issue can be posed at two levels -- that of the individual land owner (a financial analysis) and from a societal perspective (a formal "economic" analysis). Not surprisingly, most decisions are made on the basis of a narrow financial analysis. In order to analyze the different management options, however, the societal approach is used and a modified benefit-cost analysis framework adopted. For some components, such as the return from forestry activities, a conventional financial analysis was carried out. Estimates of the monetary values of the forestry benefits and costs associated with different management alternatives were made. For other components, notably the protection of biodiversity and ecological values, a cost-effectiveness approach was used. The analysis is divided into three major components: economic returns from forestry; biodiversity aspects; and recreation and tourism benefits. (Full reports on each component are available; see the list in the Bibliography).

G. Financial Returns from Forestry.

4.34 The economic and financial returns expected from managing native forests lands under various options, including conversion to plantations of exotic species, forms the heart of the analysis (Paredes 1994). The focus is on farmers and foresters in their dual roles: as land owners and as producers. As land owners the options available are either to sell, or rent land to a producer. As a producer (and many individuals are both land owners and producers) the objective is to maximize profits (returns to the land) according to given physical constraints and regulations. Someone who is both an owner and a producer receives benefits from both activities and desires to maximize land rent -- the net present value (in $/ha) of the infinite stream of net returns from the land. The financial analysis presented for both plantation and native forest systems assumes good road access. Access costs have a very direct effect on stumpage values and calculated financial returns.[7]

4.35 Financial Returns from Plantation Forests. To analyze the financial returns from establishing an exotic species plantation a Land Expectation Value (LEV) approach developed in the last century by Faustmann (1849) is used. This approach uses data on all of the benefits and costs associated with establishing and managing a forestry plantation and calculates a NPV of the infinite stream of returns from the land. The current legislative framework, as contained in DL 701, is used to define the feasible management options available to a land owner. (The formulas for the Land Expectation Value, and for the Forestry Value approach used in the financial analysis of native forest management options, are given in Annex 6.)

4.36 Using the Land Expectation Value approach, and maximizing the net present value of establishing and harvesting an exotic species plantation on open, non-forested land, Paredes estimated returns for different species and management regimes under different discount rates. (Actual returns, of course, are site specific; the results represented here are representative of the expected returns from average sites in the study transect.) Plantation options were evaluated at three different discount rates as a form of sensitivity analysis: 14%, representing the cost of capital to small landowners with limited

7. The researchers at the Universidad Austral in Valdivia have the entire study area on a GIS system that has information entered for a number of important decision variables including forest type, altitude, land use capability, slope, ownership and road network.

access to financial markets; 10%, representing the average cost of capital for large, wealthy farmers and forest industries; and 6%, representing some notion of a societal rate of time preference for forestry activities and the cost of capital to selected wealthy foreign investors. Table 4.3 shows the estimated net returns for plantation activities on good quality sites in the study transect, for both eucalyptus and Radiata pine, at discount rates of 6%, 10% and 14%. (For detailed cash flow tables see Paredes 1994).

4.37 As seen in Table 4.3, the returns from planting eucalyptus are greater than those from Radiata pine, in part because of the greater annual growth rate (a mean annual increment, MAI, of up to 30 m^3/ha/yr) and fairly short rotations, especially for pulpwood.[8] The returns for Radiata pine are based on a recently developed growth simulator, and include assumptions about differing silvicultural regimes for intensive and extensive cultivation: intensive pine cultivation, in good quality sites, includes one precommercial thinning, three prunings, and two commercial thinnings. The extensive sawlog regime, in poor to medium quality sites, involves no pruning and two commercial thinnings.

Table 4.3: Land Expectation Values for Different Afforestation Options (US$/ha; optimal rotation length in parenthesis)

Species	Site characteristics	6% Discount Rate	10% Discount Rate	14% Discount Rate
Eucalyptus				
pulpwood	good	$5,107 (13)	$1,969 (12)	$769 (10)
sawlogs	medium	$5,835 (23)	$1,829 (23)	$487 (20)
Radiata Pine				
intensive	growth rate: 30 m^3/ha/yr	$5,391 (31)	$1,291 (26)	$154 (23)
extensive sawlogs	growth rate: 26 m^3/ha/yr	$2,345 (23)	$629 (20)	$38 (20)

8. Very short rotations are possible in Chile (from 12 to 26 years), among the fastest growth rates recorded anywhere in the world. The values in Table 4.3 are calculated for average forest sites in the transect where the species are currently being planted. For example, the estimated returns to eucalyptus pulpwood production is based on three coppice harvests -- once every 12 years -- from the same stand.

Table 4.4: Forest Values for Native Forest Management Options
(US$ per ha, rotation periods in brackets)

Forest Type	First Harvest Value	Forest Value @ 6% discount rate	Forest Value @ 10% discount rate	Forest Value @ 14% discount rate
Siempreverde				
Conversion	2,163			
Selection	912	1,721 (24)	378 (20)	-9 (20)
Protection	1,967	1,036 (30)	-115 (25)	-411 (25)
Row clearcut	1,050	299 (30)	-191 (25)	-302 (25)
Coigue-Rauli-Tepa				
Regrowth-20 yrs old	400	3,961 (21)	1,404 (18)	506 (15)
Mature forest:				
Conversion	3,138			
Selection	1,562	2,496 (24)	612 (24)	91 (20)
Protection	2,488	1,305 (30)	-66 (25)	-392 (25)
Roble-Rauli-Coigue				
Regrowth-20 yrs old	400	4,656 (24)	1,614 (18)	604 (18)
Mature forest:				
Conversion	3,838			
Selection	1,542	2,836 (24)	738 (24)	124 (20)
Protection	3,155	1,101 (33)	-188 (27)	-455 (22)

Note: Regrowth refers to secondary growth by natural regeneration on abandoned agricultural or pasture lands.

4.38 The absolute levels of financial returns and the relative attractiveness of different options are very sensitive to the discount rate. For example, the intensive pine and both eucalyptus options are equally attractive on good soils at low discount rates (with LEV of about US$5,000); when the discount rate increases to 10%, however, eucalyptus becomes much more attractive because of its shorter rotation period (12 to 13 years versus 20 some years for pine). This advantage becomes even more pronounced at a 14% discount rate, the opportunity cost of capital faced by many individuals. This may explain the popularity of eucalyptus planting on small holder agricultural lands.

4.39 Within the study area there are more ha planted with Radiata pine than with eucalyptus. Based on the analysis of soil types, slope and access, as much as 100,000 ha (or 30% of the total land under native forests) may be suitable for additional plantings of exotic species.

4.40 Financial Returns from Native Forests. For land covered with native forests, the DL 701 regulations permit different harvesting regimes according to each forest type, with the exception of Alerce and Araucaria, where no harvesting is allowed (see Table 4.2). There still is considerable uncertainty about both the growth and yield rates of existing native forest resources, and the potential growth of native forests under intensive silviculture. (Note that the market prices for native forest species are less stable than for exotics; the analysis uses average prices paid in the study area.) Managing a native forest usually implies harvesting an important volume at year 0 (either from thinning or clear-cutting, if allowed) followed by the expected returns from managing the remaining trees or from whatever forest type is then established. The economics of native forest management are largely driven by the values from the first harvest. (In fact, since the cash flow then turns negative for many years, many management plans [up to 90%] are not fulfilled by land owners after the first harvest is carried out.)

4.41 In this study the Total Value (TV) approach was used to analyze the financial returns from different native forest management regimes. (The main management options considered are presented in Table 4.2, the formula for the TV approach is given in Annex 6, and typical growth rates are given in Annex 7.) The TV is composed of two parts: the First Harvest (FH) value from the initial thinning of the land in year 0, and the Forest Value (FV) component from future harvests. That is, TV = FH + FV (see Annex 6). This is functionally equivalent to the LEV approach described earlier, but explicitly separates the benefits from the initial harvest/thinning from the expected returns from subsequent forestry activities.

4.42 Not surprisingly, the largest financial benefit comes when land is clear cut (politely referred to as "conversion" in Table 4.4). With conversion, the undiscounted returns in the first year range from US$2,163 to as much as US$3,838 per ha (again depending on species and wood quality). The economic pressures to convert (clear cut) native forests and establish plantations or use the land for other purposes are strong. This option, however, is explicitly prohibited in most cases under the proposed native forest law, leading to much unhappiness on the part of both large commercial timber operations and forest land smallholders (e.g. farmers with 50 to 100 ha of land). Of course, there is an important equity issue also: if farmers have the option of either converting their land to another use, or selling their lands to large forestry plantations, it is unclear what they will do with their "windfall".

4.43 If conversion is not allowed, but some thinning is permitted, the returns from different management options are shown in Table 4.4. These returns are estimated for average quality sites within the study transect. See Paredes (1994) for more detailed information on returns from other sites. The initial FH values from thinning can be considerable, ranging from US$400 to over US$3,150 per ha for different alternatives (these values are large since the two most common options -- selection and protection -- both imply major wood harvests in the first year). For example, the selection system involves a smaller initial cut while protection involves a sizeable initial cut. These options were graphically shown in Figure 4.4.

4.44 With a 10% discount rate, a flat cost of US$15 per m^3 for harvest and transport costs, per ha values from subsequent management (FV) ranged from negative values ($191) to a high of US$1614 per ha for representative systems. Almost all Forest Value (FV) estimates turned negative with a 14% discount rate. (Lower discount rates produced higher present values, of course.) The total Value, TV, is the combination of the FH and the FV estimates. In general the Coigue-Rauli-Tepa forest type, the predominant forest type within the transect and mostly found in the Andes, had higher values than the Siempreverde (evergreen) forest types more common in the coastal range. The much less common Roble-Rauli-Coigue forest types scattered across the study area also had sizeable value.

4.45 Because of these results the conversion option will always be the most attractive financially to the land owner. This is then followed by those options that allow heavier thinning in Year 0, thereby increasing the First Harvest values. Subsequent management decisions are also very sensitive to the discount rate. An incremental 4% change in the discount rate has a higher impact on the protection system than on the selection system because of the timing of harvests: selection harvest is less sensitive to discount rate changes because harvest cycles are shorter (10 to 20 years) than even-aged management systems such as clearcutting and protection. Because of differential access to capital, small landowners, who face a higher discount rate, may find most native forest management regimes financially unprofitable.

4.46 One implication of these results is that if a strict conservation policy were implemented, native forest lands may be transferred (sold) in the long run to wealthier investors with a lower opportunity cost of capital. This change in ownership patterns can already be observed in some places and there are indications that many farmers who have sold their forest lands have drifted to the cities and joined the low wage informal sector. This is a not-unexpected outcome of the operation of market forces, but may have important social consequences, many of them quite negative. At the same time, keeping people on the land through some sort of vague Rousseauian reasoning also imposes costs, both social and economic, and may be equally undesirable as a social goal.

4.47 In sum, it appears that plantation forests of exotic species are economically more attractive on most open or degraded lands, and also dominate the returns from managed native forest stands. (Comparing the NPVs of exotic versus managed native forests systems in Tables 4.3 and 4.4 shows that at a 6% discount rate the returns from exotic plantations dominate those from managed native forests, even when the returns from initial cuttings [FH values] are included. Exotic species averaged over US$5,000 per ha while native forest values ranged from US$3,000-$4,000 per ha at a 6% discount rate.) The economic benefits from clear-cutting native forest lands are large and drive the results, and will almost always be the economically preferred option where allowed. Clear-cutting will then be followed with the establishment of a plantation of a fast-growing exotic species. There may be some areas where a combination of thinning plus improved management of native forest species may be economically competitive with exotic plantations, especially if soils or location make conversion to exotic species impractical. Experience has been, however, that since the initial financial returns are so important, many land-owners of native forests have taken the benefits from the initial thinning but have often not followed-up with the management plans designed to re-establish the native species.

4.48 Given these results, it is clear why there is such strong economic pressure on owners of native forests to degrade them via heavy thinning or clearcutting, and why there are often only marginal incentives to re-establish native forests and manage them in a sustainable manner.

H. Benefits from Biodiversity Protection

4.49 One of the primary reasons given for protecting native forests, and preventing their conversion or the large scale introduction of exotic species, is the need to protect Chile's endowment of biodiversity. Although there are considerable protected areas in the 10th Region at present (discussed in the next section), and some 12,000 protected hectares within the study transect, it is also likely that additional areas of native forest or native vegetation need to be set aside to ensure that all threatened flora and fauna are protected. This will mean some additional protection of areas forested with native species. The hard question, of course, is how much additional area is needed to meet this need. The answer, however, has to be less than the extreme of "all remaining native forests" on the one hand, and more than "only those areas presently in parks" on the other. Ideally, one would do a benefit-cost analysis of adding additional areas to the protected area system. The costs are known, either costs of land purchases or the opportunity costs of foregone productive uses if restrictions are placed on the use of private lands. It is impossible, however, to estimate the benefits of protection in a monetary sense. (The state of the art for estimating monetary values for protection of biodiversity and the expected, as yet unknown, benefits from that protection is still very rudimentary.) The best that can be done is to identify and rank priority areas for protection, and then see how much "protection" society is willing to pay for.

4.50 To help answer this question the second major component of the study focusses on biodiversity and protected areas and is derived from expert analysis based on a modified Delphi technique of the biodiversity located within the transect and the 10th region more broadly. This component is designed to identify the important vegetative systems, flora and fauna in the area, and identify needs for additional protected areas.[9]

4.51 In order to facilitate the expert group meeting, an initial report was prepared that identified a number of under-represented plant and animal species and their associated forest types, including the little appreciated coastal forests (Donoso 1993a). The expert group meeting, composed of 7 specialists -- 2 forest ecologists, a botanist, an animal zoologist, an ornithological zoologist, a mammalian zoologist and an endangered species specialist -- considered three main questions: 1) identification of important flora and fauna in the transect, 2) identification of presently protected areas, and 3) identification of additional areas in need of protection. Originally the group had hoped to develop a quantifiable measure of biodiversity that could be used to develop management plans for native forests, but this did not prove possible.

4.52 The expert group considered the great diversity within the transect from east to west, and the soils and hydrology of the area. Different forest types were analyzed, and the group was able to identify a number of threatened species of flora and fauna and recommended certain ecosystems be considered for protected status in order to protect these threatened species (Donoso 1993b). The areas identified include a number of corridors as well as several individual sites (see Figure 4.5 that displays native forest areas with restrictions, either because of slope or because the areas are candidates for inclusion in the protected area system; there is considerable overlap between the two sets of restrictions.): 1) a transect from the Coastal Range to the central valley with representative evergreen, Olivillo, Alerce and Ro-Ra-Co species; 2) Boldo forests and remaining original growth in the central valley, including stands of Roble and Laurel, Lingue and the Nadis; 3) a transect from the central valley to the high Andes that includes Co-Ra-Te, Ro-Ra-Co and Lenga forests; 4) an Andean ecosystem containing Co-Ra-Te

9. The Delphi technique is a form of expert-group meeting whereby experts are asked certain technical questions in an iterative fashion, thereby allowing time for reflection and additional information to be presented. The goal is to reach a consensus based on expert opinion, in a non-confrontational, iterative process. In this study, a "modified" Delphi approach was employed whereby the panel of experts first responded in writing to a series of questions on biodiversity needs and the flora and fauna of the transect and the region, and then met as a group to discuss the preliminary findings and to come to a conclusion on additional areas that needed protection.

and evergreen forests in the south of the transect; 5) Coastal and lakeside areas of Olivillo forests; and 6) the wetlands around Valdivia.[10]

4.53 The expert group did not explicitly consider watershed protection values. Although conversion and intervention in forested areas can create erosion and have an impact on erosion rates and the hydrology of the area, this does not appear to be a major issue in the study transect if legal constraints on removing vegetation along streams and rivers are enforced. Even though rainfall rates are high, and the topography is steep, erosion and sediment transport is not considered a serious problem (and is not visibly one either). If large scale conversion was to take place, especially on steeper slopes, this may become an issue.

4.54 Considering all the available data, the group reached the following conclusions about its ability to quantify biodiversity benefits. It agreed that biodiversity includes native vegetation, flora and fauna and that larger continuous areas are essential to provide biodiversity benefits. The share of each type of remaining native forests compared to the share under plantations and transformed areas is an important piece of information; extension of monocultural plantings are to be avoided. Finally, the costs of later mitigative measures need to be considered before threatening unique or endemic species in the native forests. Although these guidelines are qualitative and not quantifiable, they do offer some precautionary principles for consideration of additional protected areas.

4.55 The areas identified for consideration for protection amount to about 78,500 ha in the study area (this is in addition to the 12,000 ha already protected as part of the SNASPE, the National System of Protected Areas, and an 800 ha private reserve near Valdivia.) The distribution of land currently protected, and proposed for addition to the system, is shown in Table 4.5. This area represents about 23% of the total area of 334,400 ha under native forests in the study transect. Although not all of these areas are candidates for conversion or other uses (since about 35,000 ha (or 45%) are included in the "critical slopes" category that will prevent most development of these lands), many areas could potentially be developed as managed native forests, or converted to plantation forestry. If these areas had good access conditions as assumed in the financial analysis, the opportunity costs of protection (in terms of development options foregone) could be considerable, as much as US$1000-$2000 per ha. Additional analysis is needed to set priorities within the 78,500 ha. identified for protection. Which areas, or parts of areas, should be protected first; which ones later; and how much is the actual opportunity cost?

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10. A Chilean NGO, CODEFF, has also been actively involved in the native forest issue and has identified a number of areas that need to be protected, including many of those identified by Donoso and colleagues (CODEFF, 1992).

FIGURE 4.5.

NATIVE FOREST WITH RESTRICTIONS

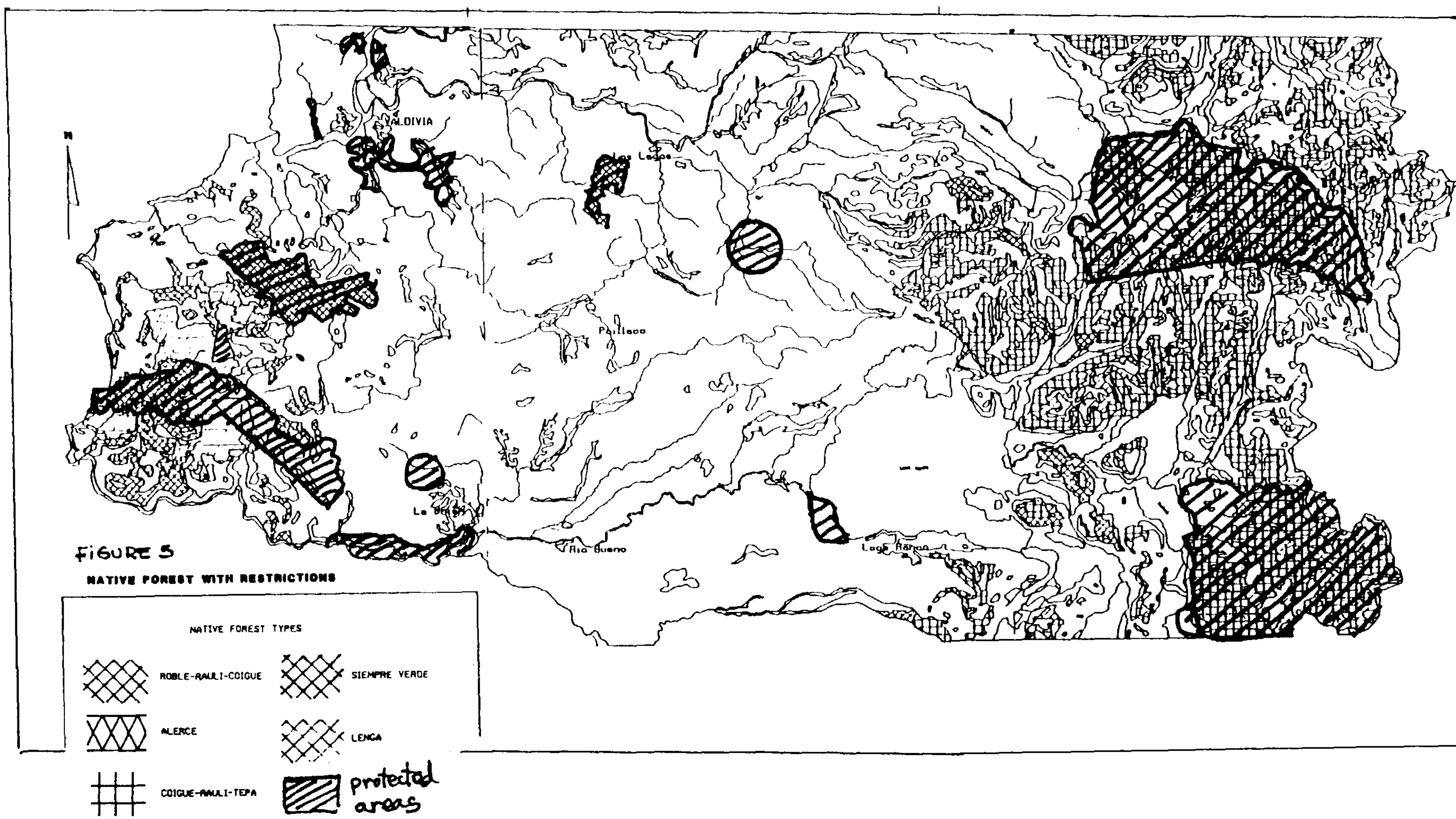

Table 4.5: Existing and Proposed Protected Areas and Physical Constraints

Forest Type	Currently in SNASPE	Proposed to SNASPE, with slope constraints	Proposed to SNASPE, without slope constraints	Proposed to SNASPE, TOTAL	Total Forest Area in Study Transect
Alerce	2,232	652	5,364*	6,016	22,028
Siempre-verde	9,780	3,448	4,708	8,156	82,152
Co-Ra-Te	0	23,068	22,832	45,900	168,028
Ro-Ra-Co	0	32	3,040	3,092	16,296
Lenga	0	7,988	7,428	15,416	45,940
TOTAL	12,012	35,208	43,372	78,580	334,444

* The 5,364 ha of Alerce are found on very thin and acid podzolic soils that should be considered as "with constraint" even though they have only a modest slope.

4.56 Almost all of the areas identified for protection are owned by large, private landowners. Of the total of 78,580 additional hectares proposed for SNASPE, over 77,000 ha are held in landownings of 500 ha or more. This is fully 98% of the total area. About 1.5% of the area is held in landholdings of 200 to 500 ha. Less than 160 ha was held by small landholdings of less than 50 ha. Clearly any discussion about expanding the protected area system will involve a fairly small number of large land owners, or corporations, not the large number of small holders often involved in other countries. The role of the private sector in protecting areas should also be considered. There is at present one small private park (800 ha.) in the study transect but more could be established. There is a precedent in activities of the Nature Conservancy and other groups in the US and in neighboring Argentina.

4.57 In sum, the opportunity costs of protection (in terms of development options foregone) may be considerable. Whether or not these areas can be added to the SNASPE, the national protected area system, will depend on funding for land purchases, or creative "bartering" between government and land owners with respect to transferable development rights. Given land ownership patterns, any expansion of the protected area system will involve dealings with larger landowners (who have easier access to capital and hence see greater potential profits from forest land), and will also involve considerable areas where most, if not all, commercial activity is prohibited because of slope or soil constraints. Still, if biodiversity needs can be met through the use of "set-asides", other areas under native forests can be considered as economic resources that can be allocated to their best and highest valued use.

I. Returns from Tourism and Recreation Development

4.58 The third major dimension of the forestry equation is the importance of tourism and recreation as an economic industry in the area (Rios 1993). Tourism is almost entirely centered on the natural resources of the area -- especially the lakes and mountains, and their forests, as the main attractions. Information on numbers and types of tourism and recreational uses, average expenditures, growth in recent years, and use of existing protected areas have been analyzed to assess the importance of forests, forest cover, and protected areas to this industry.

Table 4.6: Average expenditure per day

Country	Average expenditure/day (US$/day)
Brazil	59.9
Peru	50.1
Argentina	33.7
Other Latin American countries	50.1
U.S.A.	79.4
Europe	57.3
Other countries	62.4
Average (1)	44.1
Chile	25.0

Notes: (1) This average is for foreigners only (weighted average)

(2) These figures correspond to a 1991 estimate and include lodging, food, transportation, souvenirs, and others (SERNATUR, 1992a).

4.59 Although data problems abound in estimating tourism in the region (see Annex 8 from Rios, 1993) initial results indicate that the gross revenues of the tourism/recreation industry in the 10th region are about US$100 million per year, almost as large as the estimated US$130 million per year from the region's forestry industry.[11]

11. The recreational/tourism study was done for the entire 10th Region, not just for the area included in the transect. This was necessary since visitors go to various parts of the (continued...)

Visitor numbers are large and growing, especially visitors from Argentina and the north of Chile. Rios estimates that annual visitors to the 10th Region (an area much larger that the study transect but similar in its appeal with lakes, mountains and the ocean) total between 470,000 and 530,000, of which 65-70,000 are non-Chilean, with the largest number coming from Argentina, followed by Brazil and Peru.[12] The US accounts for about 8000 visitors, and all of Europe for another 10-12,000 visitors per year (Rios 1993). Most visitors spend 7 to 8 days in the Region. Average daily expenditures for non-Chilean visitors are about US$44, or 75% more than the Chilean average of US$25 per day (Table 4.6).

4.60 Land values. The intensive demand for recreational use, and the willingness-to-pay for these uses, is also reflected in land prices, especially in those areas near the lakes that are dotted along the length of the Andes. In lake front and nearby forested areas, asking land prices are very high, sometimes reaching levels of US$10,000 to US$20,000 per ha for small parcels of lake-front property. (Table 4.7 lists information on asking land prices for land near three of the lakes in the region. Prices per ha vary by location and by the number of ha in each lot.) These land values are heavily influenced by characteristic of the total environment, of which forests are only one component. It is interesting to note that land values on Lake Rapel, a manmade reservoir without surrounding forest lands located near Santiago, are considerably lower than those found in the 10th region, even though Lake Rapel is much more accessible to Santiago residents (Rios 1993).

4.61 In comparison to these very high land prices for areas with recreational and tourism potential, based on the results presented earlier in Table 4.3 the maximum amount that can be paid for cleared or degraded land to support forestry activities (assuming a 10% discount rate) ranges from US$1600 to US$1900 per ha for eucalyptus, US$600 to US$1200 for Radiata pine, and much less for most native forest species. (If land has forest cover that can be harvested, the land values increase accordingly.) Therefore, with land in recreational areas, especially near the Andes and their nearby lakes, ranging in price from several thousands of dollars to US$10,000-$30,000 or more

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11.(...continued)
region and the data are tabulated on a regional basis. Since values are expressed on a per ha basis, however, they can still be used to assess options in the study transect area.

12. Visitation statistics are very weak; the primary source of information is registration data provided by hotels and other lodging facilities. These data fail to pick up much informal lodging (e.g.,in private homes) or those who are camping. Rios (1993) has attempted to assess the various biases in both visitor and expenditure data and the numbers presented here are her best "guesstimate" of the actual values, realizing that there are a number of reasons why these would tend to underestimate, rather than overestimate, visitor numbers and related visitor expenditures.

per ha, "recreation" will be the highest and best valued use for selected forested areas. Recreational use, although less destructive than logging, still results in some disturbance to forests.

Table 4.7: Land Market in 10th Region
Recreation and Vacation Purposes Only
(US$ per hectare)[13]

Lot size	Lago Ranco (border)	Lago Puyehue (border)	Lago Llanquihue (border)
less than 5 has	$ 42,000 to $70,000/ha Weighted average: $ 51,400/ha	$ 12,000 to $26,000/ha Weighted average: $ 22,700/ha	No observations
5-12 has	$ 20,000 to $34,000/ha Weighted average: $ 24,800/ha	$ 10,000 to $12,300/ha Weighted average: $ 11,000/ha	No observations
Over 12 has	$ 3,100/ha Weighted average: $ 3,100/ha	$ 800 to $10,000/ha Weighted average: $ 4,700/ha	$ 11,000 to $27,000/ha Weighted average: $ 16,698/ha

Notes: Most of these figures are based on asking prices, not sales prices; therefore they are an overestimate of real market values.

Source: Several issues of Diario El Mercurio, months November 1992 through June 1993, and personal communication from a private land dealer in Valdivia (Schlechter, 1993).

4.62 Parks and protected areas. Estimates were also made of values associated with the Region's national parks and other protected areas (comprising national monuments and national reserves). The 10th Region has about 575,000 ha under protected status largely along the Andean range, or 8% of the total land area in the Region (see Figure 4.1). Most of the protected area is in National Parks (about 489,000 ha), with smaller areas in National Reserves (85,000 ha) and Natural Monuments (2,300 ha) (CODEFF 1992 and CONAF 1993). About two-thirds of the Region's protected area is covered by native forests.

4.63 Visitation to protected areas is increasing rapidly in Chile and in the 10th Region. Table 4.8 presents visitor information to all protected areas and those in the 10th

13. Based on an exchange rate for peso conversion of Ch$405 per US$.

Region from 1986 to 1993. In 1993 the 10th Region accounted for almost 30% of the 840,000 registered visitors to all protected areas in Chile, and the rate of growth of visitors to protected areas in the 10th region has been over 11% per year between 1986-1993, double the national average of 5%. As with visitor information in general, there is probably considerable under-reporting of visitors to protected areas given the limited number of park personnel available to register visitors.[14]

4.64 Average stay at the national parks was fairly short -- a CONAF official estimated that the average length of stay was 2 days in N.P. Puyehue and 1 day in N.P. Vicente Perez Rosales, the two most popular parks. Based on the available data Rios (1993) estimated that tourism expenditures were about US$5.4 million for these two parks in 1992, not a huge number but still sizeable and growing rapidly. Based on the gross revenues generated by recreational use of each national park, and an assumption about modest future growth in visitation, estimates were made of the gross tourism revenues associated with visits to selected National Parks in the region. Some of these numbers are very large. Rios estimated the capitalized value of future tourism expenditures over a 50 year time horizon, with a 5% annual growth in visitation. Using a 10% discount rate, the capitalized value of gross tourism expenditures associated with PN Vicente Perez Rosales is about US$43 million, or about US$560 per ha.; for PN Puyehue this capitalized value is about US$34 million, or about US$1060 per ha.[15] (The per ha values are estimated by dividing total revenues by an area equal to 30% of the total area of each park, on the assumption that only about a third of the area is actually available for use. If the per ha values were calculated over the entire area of each NP, they would be proportionately reduced.)

4.65 Since National parks tend to be very large and the areas actually used are only a small portion of the entire protected area, these figures are quite sizeable on a per ha visited basis, even when adjusted from a gross to a net revenue basis. If additional resources are available, a proper travel cost study could be conducted to estimate

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14. Two National Parks, Vicente Perez Rosales (VPR) and Puyehue, account for over 90% of reported visitors in the Region. This is due to their good access and their attractions -- thermal baths, hiking and skiing in Puyehue, and waterfalls, lakes, and passage to Argentina in VPR. Foreign visitors accounts for about 12-14% of all visitors to protected areas in Chile, and their numbers are increasing more rapidly than Chilean visitors. This is important to the economy since foreign visitors spend some 75% more per day on average than Chilean visitors. For more details on tourism in the Region see Rios (1993).

15. Information from National Park officials indicates that while visitor counts for PN VPR are fairly accurate, those for PN Puyehue may capture only 30-40% of total visitation, thereby seriously underestimating the gross economic expenditures associated with this park.

consumer's surplus associated with National Park recreation. As it is, one can only say that National Parks generate a sizeable amount of tourism and recreational expenditures for the local economy and are an important part of the tourism industry in the Region.[16]

Table 4.8: Visitors to protected areas in the 10th Region

Year	Chile - Total Visitors	10th Region	Growth Index (1980 = 100)	Relative importance of 10th Region (%)
1986	588,213	98,477	100	16.7
1987	588,680	118,936	121	20.2
1988	276,476	119,445	121	43.2
1989	736,843	136,383	138	18.5
1990	732,070	130,982	133	17.9
1991	752,213	139,647	142	18.6
1992	782,071	184,320	187	23.6
1993	840,290	241,121	245	28.7

Source: CONAF statistics, 1986-93

4.66 In sum, recreation and tourism are substantial and growing industries in the Region. The importance of these uses will grow rapidly in the future as incomes increase and more Chilean and foreign visitors come to the area. Forests and protected areas are an important part of the overall attraction, especially when combined with the lakes and volcanoes that the Region is famous for. It is less clear what impact changes in forest cover will have on this sector -- at one level (and from a certain distance) it may not matter greatly if hills are covered with native species or exotics. Of course, in parks and other protected areas where the interaction with the forest is very direct, native forests, with their wide diversity of flora and fauna, are much more desirable than plantations of industrial species. Watershed impacts of changes in forest uses are potentially important if they result in decreased clarity of stream and lake water. The tourism/recreational dimension, therefore, becomes the third element in the complicated process of allocating forest lands among competing uses.

16. Note that these values for tourism/recreational expenditures associated with National Parks are gross capitalized amounts over a 50 year period. The annual values of recreational expenditures, upon which these capitalized values are based, are part of the overall estimate of yearly tourism and recreational expenditures previously cited for the Region.

J. Implication For Native Forest Management

4.67 This study has indicated the complexities and uncertainties involved in analyzing management options for native forests in Southern Chile. Certain implications, however, can be drawn from the analysis. It seems clear that the strict prohibition of any conversion or introduction of exotic species will impose an unacceptable cost -- both on small landholders who are forced to survive on fairly modest returns from their stands or convert them clandestinely into firewood for sale in the local market, as well as large firms who have built an important and dynamic industry on plantation forestry and the processing and exporting of forest products. On the other hand, there are legitimate concerns about biodiversity conservation and the danger of market forces leading to the wholesale "conversion" and chipping of native forests. Is there an equitable and fair compromise that will satisfy both ecological and economic criteria? Our initial results indicate that there are interesting possibilities of meeting these potentially conflicting goals.

4.68 It was not possible to estimate the monetary "values" of protected areas. Estimates were made of the gross expenditures per ha associated with the use of selected protected areas over a 50 year time horizon. These values ranged from US$500 to US$1000 per ha, considerably less than the expected returns from forestry (that are similar in magnitude but represent net values), but still substantial sums considering the large areas protected. In addition, these values are probably underestimates since CONAF does not keep an accurate registration of visitors, and some users are not counted.

4.69 The decision to protect areas can not be made based on a benefit-cost calculation (and in fact this is never done anywhere in the world). However, as seen in Chile protected areas can be associated with substantial use and revenues (benefits) and more work is needed to better quantify these benefits. Improved infrastructure at national parks should increase use and create larger recreational benefits, as well as produce more tangible economic returns from admission fees, concession fees, and other activities.

4.70 In areas not suitable for recreation or tourism development, other options must be considered. If access is difficult or soils are poor native forests will predominate; in other locales conversion to exotic species plantations or mixed-species forests will be the outcome. The economic benefits from conversion to other forestry systems appear to be substantial in many cases, especially with the potential for sizeable net benefits from initial land clearing. One has to be careful, however, that the decision on conversion is not based solely on financial returns. Native forests provide other benefits--habitat, landscape values (discussed later), and soil and water protection benefits. These are difficult, if not impossible, for the landowner to capture. Hence the pressures for conversion. The representative numbers presented in this paper indicate that the potential increase in financial returns may range from several hundred dollars to many thousands of dollars per ha. Within the study transect, the areas potentially available for conversion or alteration may be as much as 100,000 ha or more (largely Siempreverde and Co-Ra-Te forests), or a third of the total area presently under native forest (see Table 4.9 and Figure 4.6 for details on these areas). If only 20% of this area was converted to exotic species plantations, the increase in NPV of plantations over managed native forests would be as much as US$50 million.

Table 4.9: Allocation of Forest Lands Located in the Study Transect (ha)

Forest Type	Presently protected	Proposed for protection	Lands with slope or soil constraints	Total lands with constraints*	Potentially productive lands**	TOTAL forest lands
Alerce	2,232	6,016	2,908	22,028	0	22,028
Siempre-verde	9,780	8,156	26,980	39,144	43,008	82,152
Co-Ra-Te	0	45,900	90,980	113,812	54,216	168,028
Ro-Ra-Co	0	3,092	5,836	8,892	7,404	16,296
Lenga	0	15,416	26,936	34,364	11,576	45,940
TOTAL	12,012	78,580	153,640	218,240	116,204	334,444

Note: *The total area with development constraints may be less than the sum of the previous three columns due to overlapping constraints. ** Part of the area indicated as potentially productive may have severe accessibility or weather restrictions.

4.71 The financial analysis of plantation and native forest management options clearly illustrates the forces that are driving much of what is happening today in the forestry sector. As seen in Tables 4.3 and 4.4, and assuming an intermediate discount rate of 10%, a landowner has a number of clear options. If land is already cleared or is degraded scrub land, the most financially attractive option is to plant eucalyptus or Radiata pine. The expected LEV (the NPV of an infinite stream of forestry production) should be between a low of US$600/ha for extensive pine cultivation to as much as US$1900/ha for pulpwood eucalyptus production on a 12 year rotation. In this situation establishing native forest species would probably result in a loss, that is, in a negative LEV.

4.72 If, on the other hand, the land is already under native forest species, there are a number of different management options. If there are no restrictions on what the landowner can do the choice is usually very clear -- clearcut the land (conversion) to capture the sizeable one-time benefit from the forest stock and then replant with quick growing exotic species. This approach yields initial benefits of from US$2,000 to

US$3,800 per ha from the First harvest (FH) plus the previously cited returns from plantation forestry.

4.73 However, if conversion is not permitted and native forest lands must be kept under native forests, then the expected returns will consist of the First Harvest values plus the estimated Forest Values (FV) from subsequent production (see Tables 4.4 and 4.10). The choice is usually between some version of the selection system and the protection system. The selection system produces lower FH values but higher FV from subsequent management. In contrast, the protection system gives the reverse result: higher FH values and lower FV values. As seen in Table 4.10, the total expected value is always greater under the protection system rather than the selection system, even though the expected returns from managing the native forest (the FV value) under the protection system are negative! Herein lies the core of the native forest management problem -- the financial results favor those systems that have greater harvests in the first year, and actively discourages subsequent management because the management component usually results in a negative expected value. This is reflected in the widely noted failure of landowners to follow CONAF approved management plans once the initial harvest or thinning has taken place. The result is a rapid degradation of the same resource that the management plan was designed to protect. Weak forestry institutions make effective management extremely difficult. The existence of this market failure--between the social objective of productive, sustainable native forests and quick private financial returns--indicates an area where active intervention may be necessary if Chile's native forests are to be managed on a sustainable basis. Subsidies or tradable development permits may be needed, depending on size and resources of the landowner.

4.74 Barring strict enforcement of management plans, however, and based on the assumptions and the results presented here, the following points can be made:

- there will always be a strong financial incentive to plant exotic species (eucalyptus and radiata pine) on previously cleared land;
- there are strong financial incentives to convert native forest lands to exotic species plantations;
- when conversion is not allowed, there are strong financial incentives to select the native forest management regime that maximizes the initial harvest and then abandon subsequent management plans, thereby avoiding the loss of several hundred dollars per ha.
- all of these tendencies are reinforced at the higher discount (interest) rates commonly faced by smaller landowners.

FIGURE 4.6: POTENTIALLY PRODUCTIVE NATIVE FOREST

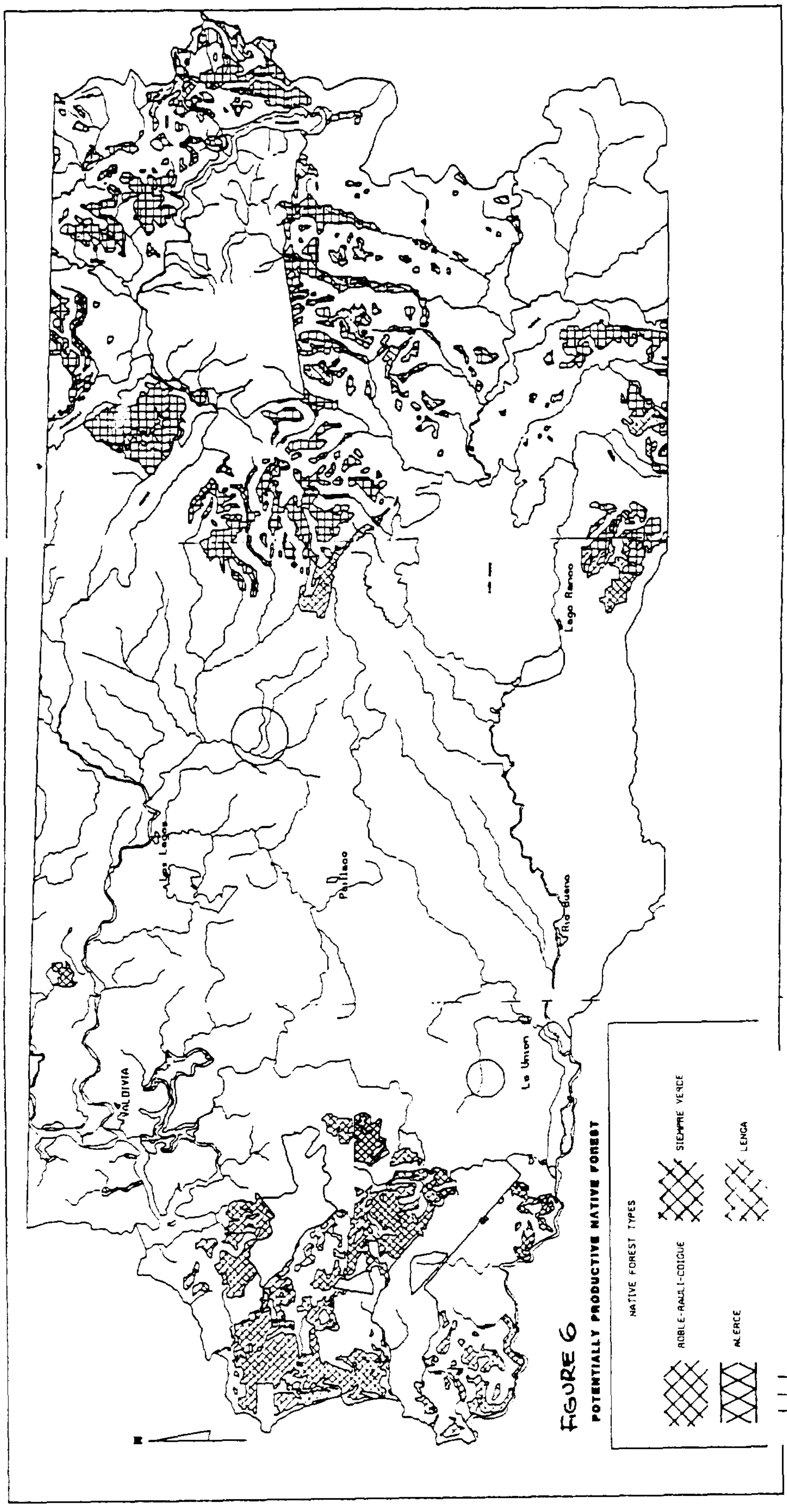


Table 4.10: Expected Returns from Different Forest Types and Management Regimes, LEV Approach, 10% Discount Rate

Forest Type and Management Regime (area potentially available)	FH -- First Harvest ($/ha)	FV -- Forest Value ($/ha)	Total Expected Return ($/ha)
SV (43,000 ha) Selection	$912	$378	$1290
Protection	$1967	(-$115)	$1849
Co-Ra-Te (54,200 ha) -- Selection	$1562	$612	$2174
Protection	$2488	(-$66)	$2422
Ro-Ra-Co (7,400 ha)-- Selection	$1542	$738	$2280
Protection	$3155	(-$188)	$2967

Note: SV = siempreverde (evergreen); Co-Ra-Te = Coigue, Rauli, Tepa; and Ro-Ra-Co = Roble, Rauli, Coigue.

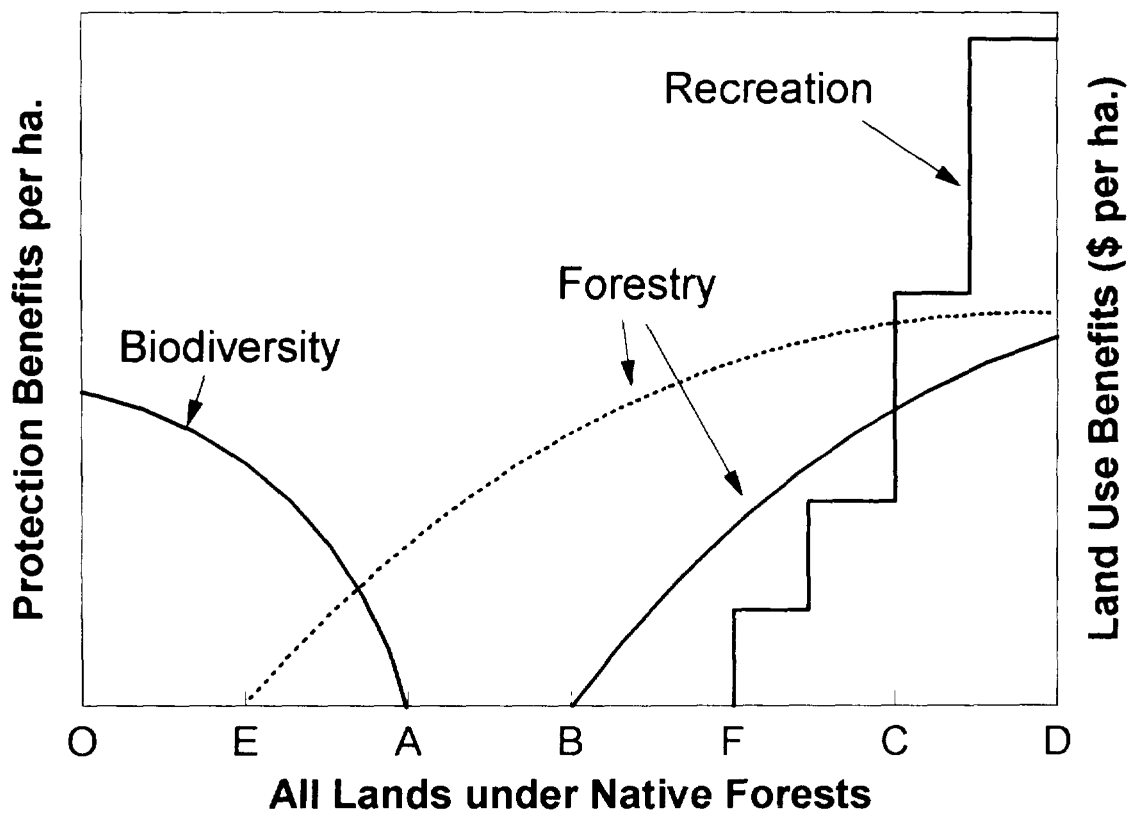
4.75 There are other social, non-biodiversity related reasons for retaining certain areas under native forest. Small land owners may not have the capital and market access to successfully compete in the plantation sector. If they sell their land for short-term gains they may have to leave their land and move to the towns and cities of the region. Legislation may be used to introduce incentives for retaining land under native forests (and improving the level of management and returns to small land owners) but it is important to ensure that the expected benefits justify the costs. Since the number of variables are large, and the level of uncertainty over productivity of native forests is also large, careful analysis is needed to correctly identify the trade-offs involved.

4.76 One way to consider the overall tradeoff between protected areas, recreational use and conversion to other forestry systems is seen schematically in Figure 4.7.[17] Conceptually, the total area of native forest under consideration is represented by the length of the horizontal axis, OD, and we consider three alternative, and sometimes competing uses: protection, recreation and conversion. Since protection is handled by use of a set-aside, and the values per ha of protected land are not expressible in monetary terms, the area protected is represented by the line on the left-hand side of the graph, and the unit on the vertical axis is some measure of "protection benefits per additional ha.

17. Mead Over of the Bank's PRDEI Division suggested this graph.

protected." This value decreases as increasingly larger areas are set aside. In this example, an area equivalent to 0A is set aside for protection. The other two uses, recreation and forestry, are represented by the solid lines on the right hand side of the figure -- here the vertical axis represents financial returns per ha. As shown, for some areas recreational uses clearly dominate (e.g. the area CD) and it is only at lower returns that different forestry options enter, usually involving changes in the native forest regime (e.g. the area BC). Within BC there will be a mix of plantations and managed native forests. For some lands, because of their poor soils, steep slopes, or remote location, there is no attractive alternative use (e.g. the area AB).

FIGURE 4.7:
ALLOCATION OF NATIVE FOREST LANDS
AMONG COMPETING USES



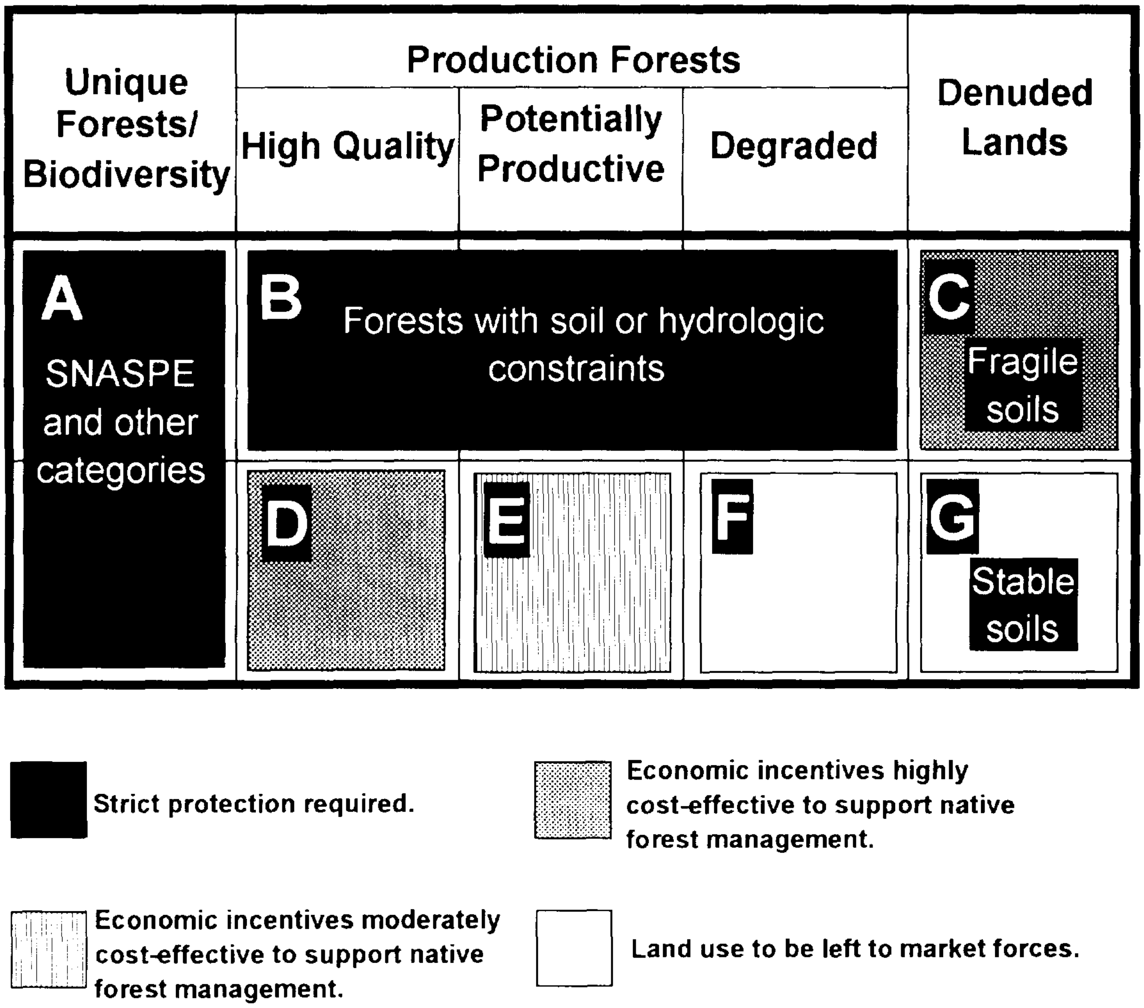
4.77 This stylized representation of the management challenge offers interesting insights. The area needed for biodiversity protection set-asides need to be identified by experts. (In this case biodiversity and other uses are represented as non-competing uses, but this may often not be the case.) For the remaining area, AD, market forces will help to allocate land among various uses. As discussed, recreational uses will easily out-bid forestry options for certain areas, as seen in Figure 4.7. The potential benefits from conversion and introduction of exotic species is large in many areas, and there will always be the private temptation to sell one's land or clear-cut native forests if that is allowed. In other areas, the returns from improved management of native forests may be an acceptable alternative. There also are areas that will largely be left alone because of locational factors or the quality of the soils.

4.78 The major analytical problem occurs, however, when the area identified for protection is large and includes lands that could profitably be developed for forestry or recreation; this situation is true in the study transect. This is equivalent to the dotted line in Figure 4.7 -- there is an area, EA, where protection competes directly with productive uses of the forest. In this case, since we cannot estimate a monetary return from biodiversity protection, we must rely on information on the opportunity cost of protection -- the alternative benefits foregone. At a 10% discount rate, these range from almost nothing for those lands where slope or soil prevent active use, to US$1800 to US$2000 per ha for lands that can only be managed as native forests (see Table 4.10), to as much as US$4000 per ha or more for lands that can be converted to alternative systems (based on the values in Tables 4.3 and 4.4).

4.79 Since the opportunity costs of alternative uses are large, the final decision becomes a political one that balances society's need for biodiversity protection against the private costs of foregone development alternatives. Interesting possibilities exist, however, for the use of creative solutions such as tradable development options, whereby large landowners protect certain areas in exchange for development rights in others. This is a very real option in the 10th Region where large landowners (over 500 ha) contain almost all of remaining native forests (97% of the total) as well as over 95% of the areas proposed for protection. In fact, a recent proposal called "2 for 1" would have private landowners pay CONAF the reforestation costs for one hectare of degraded forest land for each ha of native forest converted. Small land owners cannot usually use such an approach and must rely on direct financial compensation if they are to forego development.

4.80 The preceding analysis indicates why trade-offs exist between competing uses for native forest lands and the need to select policy tools (including regulations and prohibitions, quotas, taxes and subsidies) in an efficient way to maximize social returns from land use decisions. The selection of the correct mix of policy tools is facilitated by considering the 7 different soil-forest combinations illustrated in Figure 4.8. In this typology, lands are divided between biologically unique forests (category A), productive forest lands (categories B, D, E, and F), and bare, denuded lands (categories C and G). Although there is some overlap with the representation presented in Figure 4.7, this typology focuses on the potential productivity of different types of forested lands.

FIGURE 4.8:
POLICY IMPLICATIONS FOR DIFFERENT FOREST CATEGORIES



4.81 Category A includes forest lands that contain unique biological, ecosystem or landscape values. These values are best protected by use of set-asides as part of SNASPE or through private protection. Category B includes potentially productive forests that have severe soil or slope constraints, or provide important watershed protection benefits. Production is not allowed in these areas since social priorities outweigh potential private gains. Category C, fragile, denuded soils, are high priority areas for afforestation activities and incentives (subsidies) are probably needed to make afforestation financially attractive. Any continuation of DL 701 type incentives should focus on these areas and should be complemented with technical support programs, especially targeting poor farmers and the establishment of fuelwood plantations. In Category G, denuded, stable soils, no Government intervention is needed and afforestation with exotics or native species should be dictated by market forces.

4.82 Categories D, E and F are the most interesting from the policy perspective. If one accepts the argument that by protecting forest lands in categories A and B all unique or fragile areas are protected, other potentially productive lands should go to their best and highest valued use. On the other hand, some will argue that even with a perfectly designed protected area system (A) and protection of lands with fragile soils (B), there still remain unknowns that justify not allowing free conversion of remaining lands to exotic species plantations. If one wishes to maintain additional areas under native forests, the highly productive native forests in Category D offer the best option: the financial returns under managed native forest systems are closest to those from industrial plantations, mostly because of the high value of the first harvest. Therefore, in these situations prohibiting conversion will have a lower opportunity cost to the land owner than on more degraded lands. Nevertheless, if conversion is prohibited in Category D lands some subsidy will probably be required so that the expected return from these lands managed as native forests will roughly equal that expected from plantation forestry.

4.83 Category E and F lands could be more open to conversion. In Category E lands, potentially productive forest lands, land owners could be taxed via a "conversion fee" for each ha converted. This fee would in turn be used to help subsidize management of areas retained under native forests. For Category F lands, those that are severely degraded, policies could allow either afforestation with native forests (with some subsidized assistance) or unconstrained conversion to plantations (without assistance).

4.84 Matching policies to the potential productivity of different types of land (while protecting unique or fragile areas) offers the possibility of harnessing economic forces in an efficient manner to obtain greater economic returns from the forestry sector, while still promoting sustainable forest management. It recognizes that Government resources are limited and that active intervention (in the form of subsidies) should be restricted to those areas where such actions are clearly needed, and likely to pass the dual tests of being effective and cost-efficient. For example, by identifying those areas where sustainable native forest management is almost competitive with plantation forestry or other uses (as in Category D lands in Figure 4.8), scarce financial resources can be targeted to promote sustainable native forest management. The management challenge involves matching social needs, with land capability, with a mix of policy tools.

K. Conclusions and Recommendations

4.85 Based on the analysis of the forces involved in determining management options for native forests in a representative transect in southern Chile, the following conclusions are drawn: **First**, the financial benefits of allowing conversion of native forests are large, often as much as an additional 100 percent, or US$2,000 to US$2,500 per ha., as compared to managing these lands as native forests. Comparing returns shown in Tables 4.3, 4.4, and 4.10 clearly demonstrates that clearcutting (or heavy thinning) followed by the establishment of exotic species produces expected values in the range of US$3,500 to US$5,000 per ha. (at a 10 percent discount rate), double the expected return from managed native forests (Table 4.10). These are large numbers when one considers that 50,000 to 100,000 ha. in the study transect are potentially involved.

4.86 Once biodiversity needs are met through the use of set-asides, other forested areas (as well as non-forested lands) should be considered as economic resources that should go to their highest and best-valued uses. In some cases this will be as protected areas or for recreational and vacation use. The market prices for recreational land are sufficiently high (ranging from a low of several thousands to a high of several tens of thousands of dollars per ha) to ensure that they will not be purchased for conversion to plantation forestry. (Note that areas privately developed for recreation and tourism provide some protection to native forests but also often imply considerable changes to the ecosystem, e.g. construction of facilities and introduction of new species. Parks and protected areas, however, can be developed in a way that allows recreational use with minimal impact on the environment.)

4.87 The rapid growth, and economic importance, of the tourism/recreation business in the 10th Region requires increased government and private sector investment in infrastructure and facilities for visitors. CONAF will need to expand and improve its visitor handling facilities to accommodate increased use of protected areas while avoiding unnecessary damage to fragile ecosystems. Private concessionaires can play an important role in providing visitor services within parks. At the same time, the growth of privately funded "ecological developments" (including both resort areas and productive facilities such as aquaculture), that claim to be done in an environmentally-friendly manner, also require supervision to minimize negative environmental impacts from domestic sewage, waste water, and other potential problems.

4.88 **Second**, biodiversity protection goals will not be met by relying on market forces. There are additional areas that should be protected to preserve all major representative flora and fauna in the study transect, and these areas must be evaluated within the wider context of similar ecosystems in the Region. The group of experts identified 78,000 ha of forest land that could be considered for protection. About half of these lands have limited development potential because of slopes or soil. The other half, however, have economic opportunity costs that range from several hundreds to several thousands of dollars per ha. The required protection can only be accomplished by intervention, usually by the Government, but also in theory by private parties. The advice of "expert groups" is needed to identify those areas that need to be protected, usually through some sort of set-asides as part of the protected area system (SNASPE).

Since it is unlikely that this entire are can be protected, priorities need to be set among those areas identified for protection.

4.89 When there are several areas that provide the same biodiversity benefits, economic analysis can help to determine which is the least cost alternative. In this regard, biodiversity needs must be met within a broader ecosystem context, not on a region by region or province by province basis. Only by taking a broader view can the most cost-effective mix of areas be selected. (Economic analysis, however, is poorly equipped for identifying those areas that should be protected based on any type of benefit-cost analysis since the economic benefits of biodiversity protection are extremely difficult to quantify.)

4.90 **Third**, in addition to biodiversity, the economic approach ignores another potentially important area where intervention is still needed and brings us to our final major finding. In addition to biodiversity, there is another case where markets will fail. There may be substantial landscape value in certain forested hillsides behind lakes and recreational areas. If these hills are clear felled and converted there may be major costs to recreational users plus the potential for sediment-related damage to the rivers and lakes downstream. This landscape value is important, and will in most cases not be provided by the market since the provider and the consumer are separated and we have a classic economic externality. Again, as with biodiversity, intervention will be required, plus some sort of transfer payment or tradeable development permit to compensate those providing the "landscape values".

4.91 Landscape values do not necessarily have to be provided by untouched native forests, however. There are many interesting examples of "managed landscapes" that also provide such benefits. In Switzerland, for example, the Alpine landscape is very altered but is managed in such a way that the valuable landscape benefits are provided by what is essentially a man-made landscape of farms, pasture, and woodlots. Similarly, recent programs in Valdivia to manage the timing and extent of forestry activities along the Rio Valdivia are designed to protect scenic values between Valdivia and Niebla. To obtain these benefits, some give and take is needed on both sides -- Government and private land owners.

4.92 In sum, the results of the analysis indicate that there are substantial opportunities for efficiency gains from considering alternative management plans for native forests in Chile <u>if the legitimate biodiversity needs of the country are taken into account</u>. In other areas, the trade-off between tourism/recreational uses, exotic species plantations, managed native forests, and unmanaged forest lands will be largely determined by market forces and legislation. Clear-cutting or heavy thinning of native forests will produce sizeable financial returns for land owners but will not always ensure that replanting, with native species or exotics, takes place without some forms of regulation and active financial intervention. This is one case where a <u>laissez-faire</u> policy will likely result in excessive degradation of native forest lands. Exciting possibilities exist for trading development options, especially in the case of large private landowners, to help insure that protection needs are met without excessively restricting economic opportunities on native forest lands.

4.93 The special social and economic needs of small holders must be taken into account; they stand to lose if market forces alone determine land ownership and allocation. Without realistic programs of different development options, and some government assistance in many cases, the result will be slow degradation of native forest lands through extraction of firewood and selected species. Nevertheless, the economic and financial costs of outlawing conversion options are so large that the prohibition of conversion of native forests lands would appear to impose unacceptable social and private costs.

V. ELEMENTS OF AN ENVIRONMENTAL STRATEGY FOR CHILE

5.1 Chile has achieved economic stability by pursuing a consistent strategy of market-based and export-driven economic development. However, environmental problems arising from market failures were often overlooked. Now, pollution affects the health of many Chileans. Also, the degradation of the natural resource base threatens to undermine elements of the export-oriented growth strategy that depend on these resources. The government has taken on the challenge of integrating environmental concerns into economic policy-making. It is now recognized that within Chile's free market economic policies, sustainable and efficient economic development can only be assured if it is based on sound environmental protection and natural resources management. Considering the short time, very significant progress has been achieved; however, many steps still need to be taken to integrate environmental concerns into decision making in all sectors.

5.2 This section presents some elements for the further development of an environmental management strategy for Chile. First, the basic principles are laid out, on which an environmental strategy should be based. The analytical framework for determining and achieving the efficient level of environmental protection is introduced as it is applied to specific problems in Chapters II-IV of this report. Following an analysis of trends and linkages between environmental policy and other economic policies, the section concludes with preliminary lessons and policy priorities.

A. Principles of an Environmental Strategy

5.3 The first principle of an environmental strategy is the application of integrated environmental management based on the comparison of costs and benefits. In the past, the costs and benefits of using environmental resources have been assessed in isolation from each other, leading to fragmented and contradictory policies. On the one hand, policies that ignored the costs of environmental degradation have led to unnecessarily large environmental costs. On the other hand, environmental policies determined without regard for the costs of environmental protection were often unrealistic and left unenforced. In contrast to past practice, integrated environmental management is based on a conscious decision about the use of the country's environmental resources. Environmental economics provides the tools and methodologies for systematically integrating environmental problems in economic analysis, based on a comparison of costs and benefits of environmental protection. Section B presents the conceptual framework and the methodologies for this economic approach.

5.4 The main strategy for achieving integrated environmental management is to let the prices of all goods reflect their full social costs, including environmental damages. If the full social cost is charged for every activity that degrades the environment, economic decisions in all sectors will take environmental considerations into account, and environmental protection can be achieved at a lower cost. Growth and investment will be directed to environmentally less harmful or environmentally beneficial activities. Proper pricing of all goods will also avoid investment being misdirected to areas where Chile does not truly possess a comparative advantage.

5.5 Chile's economy is free of gross distortions of prices through subsidies on environmentally harmful activities. Also, Chile is fortunate in its strong tradition of secure property rights, which helps move prices closer to the full cost of these resources. The challenge facing the government is to define the limits of individual property rights where the rights of others to a clean environment are violated and to expand secure property rights to those natural resources and environmental goods where they have not yet been established. Like in many other countries, the prices of most goods do not yet include their environmental costs. However, as efficient environmental policy instruments are introduced, prices will move closer to the full social costs.

5.6 A successful environmental strategy will be forward looking. A strategy of grow now and clean up later is no longer acceptable, creates high costs in the future, and potentially limits access to foreign markets. Long-term substitutability of capital for environmental resources is much higher than short-term substitutability. Therefore, environmental protection can be achieved at a lower cost if incorporated early into the design of new projects. This requires the predictable phase-in of environmental regulation. The prevention of environmental damages is in most cases more cost-effective than the mitigating measures required once damage occurs. Particularly in a phase of high growth and high investment it is important that incentives be corrected for environmental market failures since resources would otherwise be invested in environmentally harmful activities causing much higher future costs. The trends and linkages relevant for the design of a forward-looking policy are discussed in section C.

5.7 Forward-looking environmental policies are also critical for gaining political support for improved environmental management. Lenient environmental policies attract investments in dirty industries and, thus, generate future political pressure against stricter environmental policies. On the other hand, improved environmental policies attract investments in clean industries that will later voice their interest in continued prudent environmental policies. These dynamic processes are an important argument in favor of consistent and anticipatory environmental policies.

B. Methodology and Data

The Conceptual Framework

5.8 Pollution and Environmental Externalities. The objective of economic development is to increase the welfare of people. Welfare is enhanced by the consumption of marketed goods that are typically measured in national accounts. Equally, however, welfare is influenced by the quality of the environment, such as the availability of clean air and water, which are not reflected in national accounts. Therefore, while economic growth, as narrowly defined in national accounts, and environmental protection are sometimes conflicting objectives, environmental protection is an important dimension of economic development. Hence, good economic policy should be guided not only by measures of national income but also by environmental effects and other factors that influence welfare but do not enter national accounts.

5.9 One of the objectives of environmental economics is to determine the level of environmental quality that leads to the highest level of welfare. This is the efficient level of environmental quality. Figure 5.1 shows a simplistic example of determining the efficient level of environmental quality. The horizontal axis represents the degree of environmental protection or quality. At the highest level of environmental quality, the costs of environmental damages (health costs, damages to materials, erosion, etc.) are zero but the costs of protection (abatement costs or opportunity costs of reducing production) are prohibitive. At the other extreme, if no protection of the environment is undertaken whatsoever, the costs of environmental damages are unacceptably high. The efficient level of environmental protection is the level at which the sum of total costs of damages and costs of environmental protection are least. This corresponds to the point at which the marginal damage costs are just equal to the marginal protection costs (Q in Figure 5.1). This level is location specific and depends on many factors including population density and the cost of available abatement technology. (For an overview of the theoretical issues, see Baumol and Oates, 1988.)

5.10 Many countries have used command-and control instruments, such as prescribing certain technologies or imposing emission standards, to achieve the desired improvements in environmental quality. In practice, the costs of achieving environmental improvements with these instruments have often been high. In many situations, market-based environmental policies have the potential to achieve the same level of environmental improvement at a lower cost. Market-based instruments create the incentives for efficient environmental protection but leave to the market the decisions how to achieve these improvements. Market instruments include environmental taxes that would equal marginal damage costs ("Pigouvian taxes") and marketable emission permits. Because of large uncertainties and difficulties with the enforcement of regulations, there is a recent tendency to shift the burden of proof from the regulator to the polluter by applying preemptive charges or performance bonds that are based on the highest possible damage with the option of partial refund if the polluter can show that damages are less than presumed (for example through emission reductions, safe waste disposal, or reforestation).

5.11 Environmental policies that internalize environmental costs lead to efficient levels of environmental protection. They change relative prices of environmentally damaging activities. These price changes create incentives for investing in cleaner

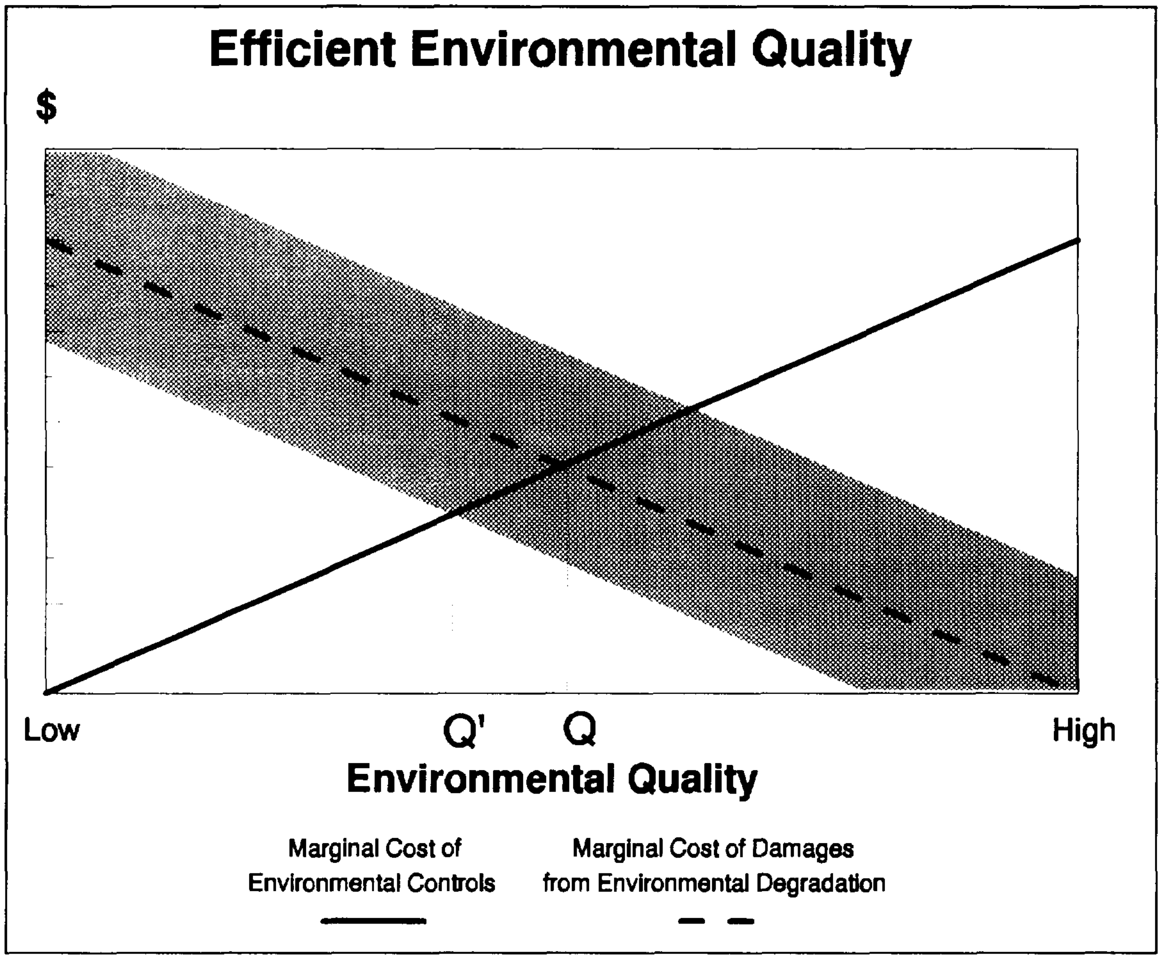


Figure 5.1 Efficient Environmental Quality

technologies. The dynamic long-term effects of environmental policy are often more important than short-term efficiency effects alone. In many sectors, the costs of efficient environmental protection constitute a small part of total production costs and have only minor effects on the structure of outputs. In some sectors, however, the costs of environmental protection can be large enough to lead to a decline in demand as a result of higher prices for goods whose production degrades the environment. Then environmental policies will change the structure of the economy toward environmentally less harmful activities. This is an efficient and desirable adjustment. If efficient environmental policies increase production costs to a level where domestic production at the current level is no longer competitive, this indicates that there is no true comparative advantage for domestic production. In this case, the absence of efficient environmental policies would have welfare costs similar to those caused by export subsidies.

5.12 Resource Depletion. The depletion of natural resources, such as mines, forests or fisheries, creates an opportunity cost since current depletion reduces the stocks available in the future. Similar to the effects of pollution, the negative effects of resource depletion are not included in the national income accounts. Therefore, it is important to guard against policies that neglect the future costs of unsustainable resource depletion. If property rights for a resource are not well established, the opportunity costs of depletion will be ignored and the resources will be overexploited. This problem applies in particular to fisheries. In this case, government policies to establish property rights, or limit exploitation by other means, are required to avoid inefficient exploitation of the resource. The depletion of forests is of concern primarily because of the positive externalities associated with forests. For these externalities the discussion of the previous section applies. For some resources, such as mines, property rights are well established. Then, market forces will bring about depletion rates that are efficient.

5.13 Even when property rights are established and depletion rates are efficient, the exploitation of natural resources raises questions about the intertemporal distribution of benefits, and ultimately about intergenerational justice. These questions are complex and not addressed in this report. As an intuitive approach to the intertemporal concerns, the concept of sustainability has gained increasing acceptance. For a renewable resource, sustainability would require exploitation at or below the rate of reproduction of the desired resource stock. For a non-renewable resource, sustainability requires the investment of revenues from resource depletion into productive assets rather than consumption. (See also Pearce and Warford, 1993.)

Application of Environmental Economics

5.14 In an applied analysis, several steps are required for determining the efficient levels of environmental protection: In the case of pollution, the process includes the analysis of the changes in emission patterns resulting from environmental control measures, the ambient environmental quality resulting from a particular pattern of emissions (estimated with dispersion models), the physical damage arising from a particular quantity of a pollutant (often estimated with dose-response functions), and finally the valuation of damages. Common methods for valuing environmental damages include the estimation of costs of illness, productivity changes, and human capital. In other methods, values are derived from hedonic prices (prices implicit in price differential of marketed goods such as houses), travel cost (for location specific environmental goods), or contingent valuation methods (based on surveys).

5.15 The concept of comparing the marginal cost of environmental damage with the marginal cost of improving environmental quality is applied to the evaluation of costs and benefits of different policies for the management of air and water quality as well as forest resources in the detailed analysis of chapters II, III, and IV of this report. These chapters demonstrate the methodologies for improving environmental management based on limited available data. In the analyzed practical situations, it was not possible to calculate marginal costs of damages and controls for all levels of environmental quality.

Instead, the costs and benefits of discrete policy packages are analyzed. This is a first order approach for changing environmental quality in discrete steps (discrete jumps along the horizontal axis in Figure 5.1). As the availability of data will improved, it should be possible to refine these approaches.

5.16 The study on water pollution contains the estimation of health effects from the current levels of microbiological water pollution based on epidemiological studies. These health effects are evaluated at the cost of treatment in addition to the productivity loss from illness and premature death. Additional costs of water pollution are the foregone income of farmers who are not allowed to irrigate certain high-value crops with polluted irrigation water. The costs of water pollution are compared with the cost of environmental improvements, in this case consisting of the costs of wastewater treatment.

5.17 The air pollution study applies a similar methodology. Costs and benefits are compared for a discrete package of measures for air pollution reduction (the control scenario). The benefits are calculated from the reduction in health damages resulting from improvements in air quality. First, the emission reductions in the control scenario are estimated. Second, the effect on ambient air quality is estimated with a dispersion model. Third, the reduction in illness and premature death from the improved air quality is estimated using dose-response functions. Fourth, the reduction in health damages is evaluated as in the water pollution study. Fifth, the benefits from the control scenario are compared to its costs.

5.18 In most cases, there is uncertainty about the physical effects of environmental deterioration and their valuation. However, the lack of reliable information should not be used as a justification for delaying effective actions for improving environmental management. Both, the water and air pollution study evaluate only a few of the benefits from pollution reduction. For example, the non-production benefits of improved health and the value of improved visibility and reduced material damage are ignored. Even without complete information about the benefits of environmental improvements, a lower bound for desirable environmental quality can be established in many cases. Figure 5.1 shows the uncertainty about the costs of environmental degradation as a shaded band. A lower bound estimate (the bottom edge of the shaded band) is sufficient to justify environmental improvements up to level Q'.

5.19 The air pollution study concludes that the lower bound estimates of benefits are sufficient to implement the air pollution control scenario. In the water pollution study, on the other hand, lower bound estimates of health benefits do not fully suffice to justify wastewater treatment. It is shown, however, that if other benefit categories, such as export losses, are included, wastewater treatment is likely to be desirable. Additional analysis is suggested in the latter case.

5.20 The study of management options for native forests is based on the same analytical framework. In this case, the costs of environmental protection (conservation of native forests) are the potential profits from clearcutting the forest and converting it to its most profitable use minus the profits from managing the forest in a manner that preserves its ecological value. The benefits from environmental protection include the value of standing native forest for tourism and watershed protection as well as the biodiversity value. This study does not attempt to value biodiversity in monetary terms. Instead, an expert panel has been asked to determine the priority areas for biodiversity protection. The study analyzes options to achieve the desired level of biodiversity protection at the least possible cost.

5.21 The approach taken with the value of biodiversity in the forest study is similar to other cases of large uncertainty, where environmental standards (such as ambient air quality standards or minimum habitat sizes required to preserve certain species) are determined as "safe" from previous experience. Instead of applying cost-benefit analysis, the best policy option is then selected by cost-effectiveness analysis, which determines the policy option that meets the standard at the lowest possible cost. Also, if there are social or political reasons for achieving a particular target level of environmental quality independent of efficiency considerations, cost-effectiveness analysis would be applied to select the least-cost option for achieving this target.

National Income Accounting

5.22 The limitations of conventional measures of economic activity, such as GNP or national income as indicators of social welfare, have been known for decades. Conventional national accounting essentially measures economic market activity only. Many environmental goods that enhance welfare are not marketed and not included in national accounts. When the production of marketed goods leads to negative environmental externalities, only the output of the marketed good but not the decline in welfare due to the environmental externality is counted in national income. Similarly, the depletion of natural resources is usually not deducted from national income measures, even though this depletion implies a reduction in wealth similar to the depletion of an inventory of manufactured goods.

5.23 Conventional national income measures can be misleading as guide for policy-making since they ignore environmental degradation. Alternative indicators of social welfare have been developed to provide policy-makers with better information than that of conventional national accounts. Case studies in Mexico, Papua New Guinea and several industrialized countries show that despite many technical obstacles it is possible to adjust national income measures for resource depletion and environmental degradation (see Lutz, 1993). Obviously, the adjustment of national income accounts for resource depletion is particularly important in a country that depends as much as Chile on the exploitation of natural resources. To improve the information base for informed policy-making, an office for environmental accounts was recently established in the Central Bank. Work has begun on a satellite accounting system that would complement the national accounts with environmental and resource accounting data. This work is still at an early stage and currently focusses on the effects of the depletion of natural resources in the forest, fisheries, and mining sectors.

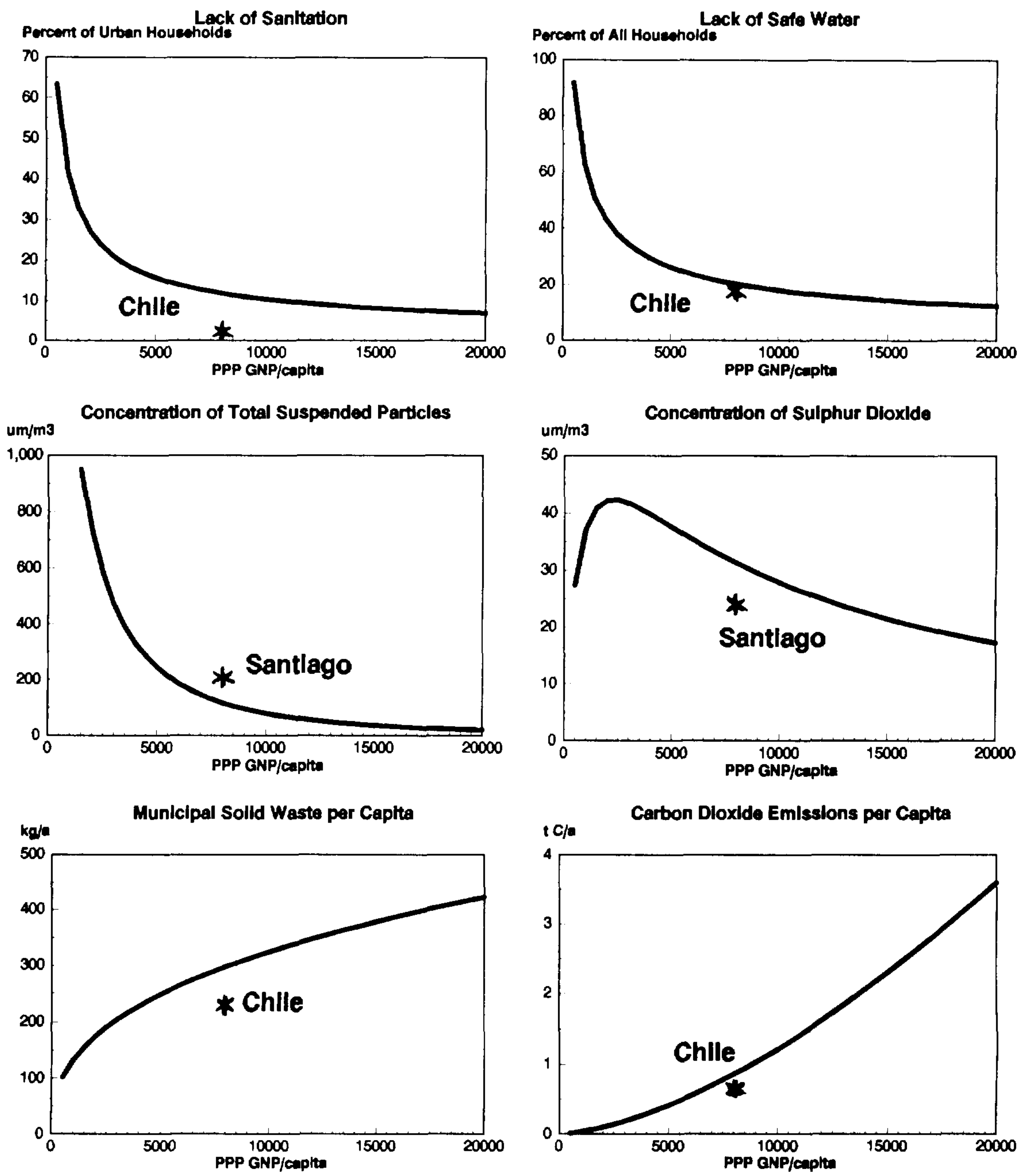
C. Trends and Linkages

5.24 Environmental problems are closely linked with other aspects of economic development and cannot be analyzed in isolation from them. Environmental trends are linked to the structure of the Chilean economy and the economic development strategy of the government. Environmental policies can redirect investment flows and change the long-term structure of the economy. On the other hand, economic growth will lead to new environmental challenges that can be addressed more effectively if anticipated early. There also important linkages between environmental policies and Chile's open trade regime and its strategy for poverty alleviation that are assessed on this section.

5.25 Environment and Growth. Economic growth is expected to continue in Chile, fueled by a combination of manufacturing growth, increased agricultural production, and continued mining revenues. Economic growth can have positive as well as negative effects on the environment. Figure 5.2 shows the results of cross-country regressions of various environmental indicators on purchasing-power parity income per capita (adapted from Shafik and Bandyopadhyay, 1992) and relates the current position of Chile to these regression results. Because of the difficulties in comparing some of the environmental indicators across countries, these regressions should not be misunderstood as predictions. They should rather be viewed as qualitative trends in relation to Chile's current position.

5.26 Where environmental quality directly affects human welfare, higher income tends to be associated with less degradation. Growth reduces the environmental degradation that is typically associated with insufficient investment due to poverty and low levels of income. As incomes and access to capital increases, implicit discount rates will fall, and investments that are individually profitable but also environmentally desirable will increase. Among the problems that are likely to decline with increasing investment are insufficient sanitation, deforestation from fuelwood gathering, indoor air pollution, and unsustainable farming methods on marginal lands.

5.27 Rising incomes usually go along with increasing demand for environmental amenities such as clean air, clean water, recreation areas, reduction in noise, and the like. With higher incomes the willingness to pay for an environment free of pollution will rise. In many cases, however, there are no markets for environmental quality and the increase in demand for environmental services does not directly translate into environmental improvements. Environmental policies by the government are required to satisfy the



Adapted from Shafik and Bandyopadhyay, 1992.
Lines show cross-country regression estimates for 1985, inflated to 1992-$.

Figure 5.2 Environment-Income Linkages increasing demand for environmental quality through more stringent environmental regulation or the creation of markets for environmental goods where they are feasible.

5.28 In the absence of efficient environmental policies, however, growth will lead to negative consequences for the environment. Increased income leads to higher levels of consumption of energy and material and increased accumulation of waste products, including toxic wastes, all of which are not priced at their full social costs, including the costs of environmental externalities. Rising wages also shift incentives toward more material- and less labor intensive production, reducing the profitability of environmentally sound but labor intensive practices, such as recycling.

5.29 Where the costs of environmental damage can be externalized, economic growth is likely to result in a steady deterioration of the environment. The investments resulting from higher income often lead to a reduction in local pollution at the cost of increases in regional, national, or even global pollution. Examples of this shift are the building of higher smokestacks, or the increased use of electricity, reducing local pollution from burning fuels but increasing regional, or even global, pollution from power plants. As incomes increase, environmental problems associated with high consumption levels become increasingly important, among them the emission of greenhouse gases and the production of toxic wastes. As the local environmental situation is improved, Chile's contribution to global environmental problems would be expected to increase.

5.30 Whether the positive or negative effects of growth on the environment prevail will ultimately be determined by whether efficient environmental policies are implemented. The negative effects of growth may prevail if the underpricing of environmental goods and natural resources continues. The delay in the implementation of environmental policies would then lead to even higher environmental costs in the future. On the other hand, a successful environmental strategy will strengthen the positive links between economic development and environment improvements and break the negative links. If policies are put in place that lead to full pricing of environmental goods and channel the demand for environmental quality into investments, growth is likely to lead to an improved environment.

5.31 Environment, Trade, and Foreign Investment. Chile has actively pursued an open development strategy based on a high level of exports and openness to foreign investment. Exports constitute 37 percent of Gross Domestic Product (see Figure 5.3) and are dominated by the mining sector (47 percent, four-fifths of which are copper), followed by industry (40 percent) and agriculture (12 percent). A large share of the industrial exports are resource based as well (processed fish and timber products). There are important linkages between environmental management, development of the export sector, and openness to foreign investment. There is evidence that the openness of the Chilean economy has beneficial consequences for the environment through foreign investors who apply the environmental standards of their country even if they are not

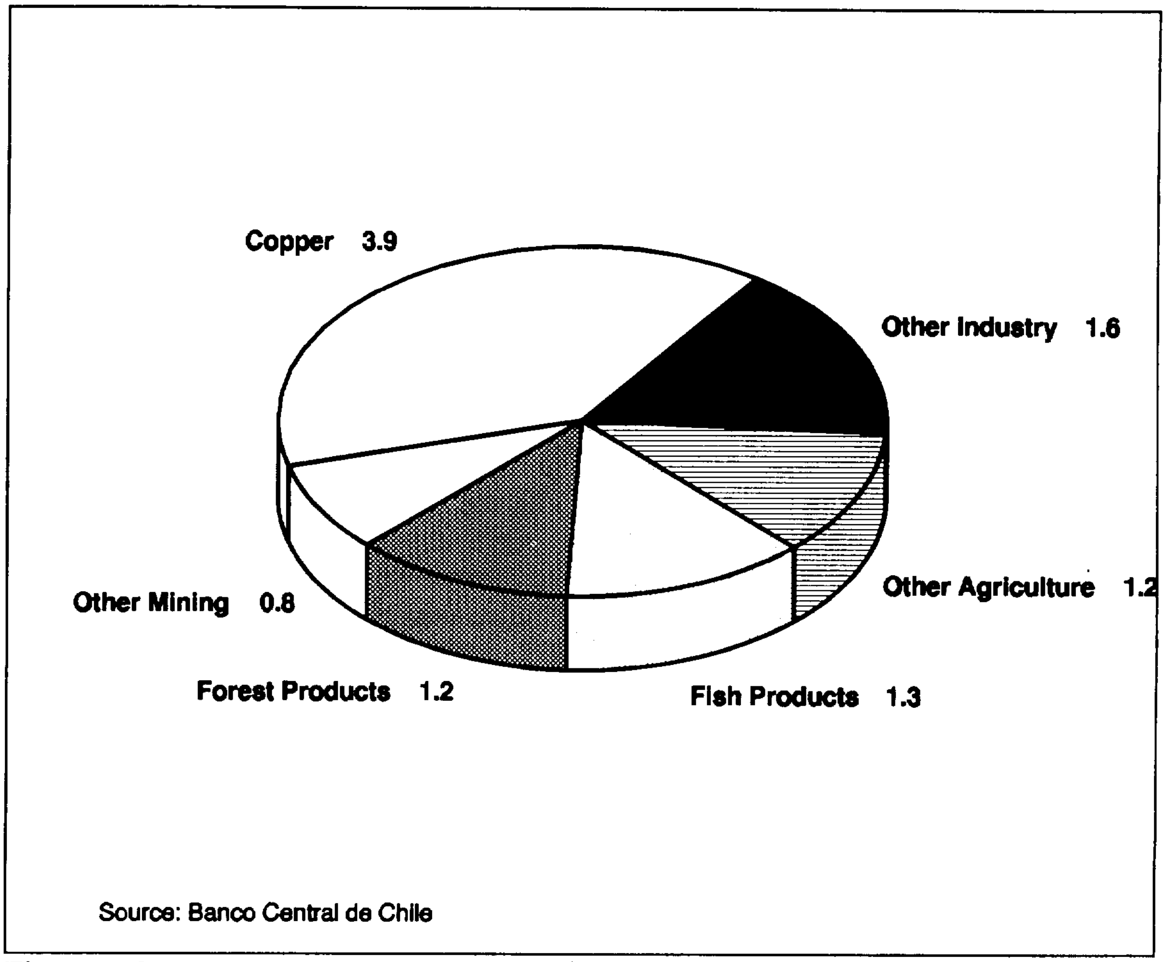


Figure 5.3 Exports in 1992 (billion US$)

legally binding in Chile (for example in the mining industry). Also foreign investment has increased the speed at which new and cleaner technologies are introduced in Chile.

5.32 There are positive linkages between environmental quality in Chile and economic integration with countries that apply higher environmental standards. Environmental restrictions of the importing country apply, for example, to the dioxin content and production methods of cellulose products, pesticide residues on agricultural products, and toxic residues in fish. These import restrictions create economic incentives not only for safeguards against chemical residues on export products but also for environmentally less-harmful production methods.

5.33 Chile's agricultural exports may also be sensitive to the perception of health standards in Chile. For example, the perceived threat to agricultural exports arising from typhoid and cholera incidence in Chile is a major reason for introducing sewage treatment. Increased trade also increases Chile's susceptibility for the preferences of consumers in industrialized countries for products produced under environmentally sound practices. Increased consumer awareness and the proliferation of green-labelling will contribute to this trend. Finally, there is a strong complementarily between the objective of promoting Chile as a tourist destination and improving environmental management. Currently, air and water pollution in the urban and coastal areas acts as a deterrent for the development of tourism to Chile.

5.34 Chile's ambitions for increased economic integration with the North American market will further increase pressures to improve environmental management. Chile is seeking to enter negotiations for joining the North-American Free Trade Agreement (NAFTA) between Canada, Mexico, and the United States. Through NAFTA and its side agreements, Mexico has been forced to undertake major environmental investments in the border areas with the United States and in the manufacturing sector. Even though Chile does not share a border with the other NAFTA countries, and its exports still consist to a large extent of raw materials, it can be expected that the conditions of the agreements with Mexico on environmental and labor standards would apply to Chile as well. It is also expected that, rather than prescribing specific levels of environmental protection, NAFTA would require Chile to effectively enforce its own environmental regulation.

5.35 On the negative side, in the absence of efficient environmental policies, trade can amplify the welfare loss from market and policy failures. The rapid depletion of native forests, the risk of overexploitation of some fisheries, and the environmental damage around mining complexes are examples of environmental costs that were intensified by the effects of trade. The approach to managing these costs, however, should not be to curtail trade but rather to enact and enforce efficient policies with regard to pollution and natural resource management. Therefore, the openness of the Chilean economy highlights the urgency of improving environmental management and regulation.

5.36 Environment and Poverty. The administration pursues a concerted effort to address equity issues and to incorporate a larger share of the population into the economic and social life of the country, especially the poor, who have not sufficiently benefitted from recent growth. In this context it is important to consider the linkages between environmental policy and poverty alleviation. In the short-run, investments for environmental improvements compete for resources with expenditures for social policies. In the long-run, however, good environmental policies reduce government expenditures directed at environmental damages, for example health care costs. Also, environmental improvements have direct implications for the well being of the population.

5.37 The costs of environmental deterioration as well as the benefits of environmental improvements are not equally distributed among the population. For several reasons, environmental degradation usually affects the poor more severely. High pollution leads to lower property values. As a result, housing in areas with high pollution, high noise levels, and inadequate sanitation is more affordable to the poor. The level of respiratory disease from air pollution in Santiago is disproportionately high among the poor, resulting from lack of heating, more dust from unpaved roads in poor neighborhoods and dietary differences. In addition, the poor lack the means for defensive expenditures against environmental degradation and have less savings to bridge the loss of earnings from pollution-related illness.

5.38 In rural areas, the poor are pushed onto degraded lands of low value. On the other hand, farming by the poor with insufficient investment on marginal lands tends to accelerate land degradation. Similarly, the depletion of renewable resources imposes a heavy cost on the poor who depend on firewood from local forests or fish in local rivers or close to the shore. Finally, unregulated small-scale mining by rural poor is a potentially large source of pollution in certain regions.

5.39 In principle, there is a strong complementarity between the objectives of poverty alleviation and environmental improvements. Environmental improvements would be expected to benefit the poor most because they are located in areas with particularly severe environmental degradation. The costs of environmental improvements, on the other hand, would be borne to a large extent by the wealthier segment of the population, which consumes larger quantities of environmentally harmful products, whose price would rise as the result of improved environmental policy.

5.40 The precise effect of improved environmental policy on the poor, however, depends on the specific situation and the policy instrument chosen, and adverse effects of environmental policy on the poor can occur. The improvement of local environmental quality, for example, can increase the cost of housing and lead to eviction of poorer tenants. Tight environmental standards can lead to the closure of production facilities which provide employment to the poor, who are willing to accept work in inferior environmental conditions. Capital intensive garbage disposal systems can destroy the livelihood of those working in informal recycling. The afforestation of degraded lands can lead to the eviction of sharecroppers. These examples highlight the importance of analyzing in detail the distributional consequences of environmental policies.

5.41 In some cases, the implementation of efficient environmental policies can lead to significant price increases, for example for energy (fuelwood) and transportation. The possible adverse effect of these price increases on the poor can be compensated by direct transfers to the poor segments of the affected population and should be no reason against the implementation of efficient environmental policies.

D. Priorities for Environmental Management

Institutional Development

5.42 Key to the implementation of an environmental strategy is the further development and strengthening of the institutional and regulatory system. Important steps have been taken with the passing of the Basic Law and the strengthening of CONAMA. In principle, the strategy of further developing CONAMA as a coordinating body, focussing on regional decision making at the level of the COREMAs, and seeking public participation in environmental management is adequate. In practice, CONAMA will face an extremely difficult task over the next years in asserting and fulfilling its new authority under the Basic Law. CONAMA and the COREMAs will require additional resources for their tasks, and in particular the administration of the EIA process, for which they are not yet adequately equipped. Also the further development of environmental management capacity in the various sector agencies at the different levels of government should receive high priority.

5.43 The passing of the Basic Law is a milestone for moving away from sectorally fragmented environmental management to an integrated approach coordinated by CONAMA. However, the next few years will be critical for the credibility of an improved approach to environmental management and the new institutional framework. In this difficult development period, CONAMA should focus on priority areas where it has the resources to achieve progress. It will be important to set realistic objectives for improved environmental management. These objectives should then be pursued by enacting and effectively enforcing regulations. The expectation that future international trade agreements will not prescribe specific environmental standards but require compliance with existing national standards further highlights the importance of realistic but effectively enforced national environmental regulation.

5.44 A major effort is required to ensure consistency in the application of environmental regulations. This consistency is critical to achieving efficient long-term behavior and preventing the costs of rent-seeking. The operation of new PM-10 sources in the Santiago Region without compensation or the logging of native forests without approval are examples of ongoing violations of existing regulations. Immediate actions for enforcement are desirable to signal the government's seriousness about its environmental policies. The strict enforcement of environmental regulation should be supplemented by the development of a system for arbitration and the resolution of conflicts about environmental regulation.

5.45 Currently, environmental regulation and management is highly centralized at the national level. In line with the overall evolution of government institutions, consideration should be given to the question whether, in the long run, to assign more authority over local environmental matters (those where external costs and benefits are not regional or national in nature) to lower levels of government. Experience from other countries suggests that local communities are often very well positioned to take responsibility for managing their environment and natural resources. The Basic Law prescribes that primary ambient standards (those for the protection of human health) apply countrywide, while (more stringent) secondary standards may vary regionally. Authority for setting the latter could be decentralized.

5.46 There is a need to move from the regulation of activities that contaminate a single medium to an integrated approach to environmental policy. Without an integrated approach, interventions for the protection of one medium are likely to shift pollution to another medium. For example, if restrictions are imposed on toxic discharges into the water bodies, it is important that proper safeguards for the disposal of sludge are in place which otherwise might be disposed of through the sewage system or cause soil contamination. An Industrial Pollution Policy Paper aimed at integrated environmental management is currently under preparation, supported by the Environmental Institutions Development Project.

Policy Instruments

5.47 Formal Regulation. Implementation of the environmental strategy will rely on a variety of instruments depending on the specific problem, including standards, environmental taxes, and market instruments. The appropriate instruments for achieving prices that reflect full social costs vary among sectors. In the case of a small number of discrete pollution sources, such as the mining sector, emission standards are often cost-effective. In case of urban air and water pollution, tradable emission permits are an attractive option for reducing the social costs of achieving environmental improvements. Chile has not yet explored the possibility of wider application of charges and taxes on environmentally harmful activities. The use of taxes as an instrument to reduce distortions (tax undesirable activities such as pollution) rather than create distortions (taxing desirable activities such as employment) is an appealing concept. A detailed analysis of proposals to shift some taxation from income and consumption to the use of environmental assets would be desirable. Possible applications of environmental taxes include transport (based on fuel use and vehicle characteristics), energy consumption, and waste disposal.

5.48 With its strong emphasis on market development and private property rights and a strong legal system, Chile is better positioned than many other countries to emphasize the development of market-based approaches to environmental protection and management. Hence, the focus of environmental policy should be on market-based instruments where they are feasible and cost-effective. The Basic Law leaves broad scope for the use of market-based instruments, for example in pollution prevention and decontamination plans. In practice, however, market-based instruments have so far failed to live up to expectations in Chile since the required stability in the institutional framework for environmental management has often not been a reality. Crucial for the effective working of market based instruments in the future will be that the details of such systems are well defined and strictly enforced.

5.49 Some of the administrative burden of environmental management can be shifted to the polluter through a prudent selection of policy instruments. In cases where enforcement problems or uncertainties about damages are significant, such as hazardous waste, liquid effluent disposal, or compliance with forest management plans, presumptive charges or performance bonds are an attractive policy option. With these instruments, charges are assessed on the basis of the worst possible damage. A polluter who shows that actual damages are less (for example because hazardous wastes have been properly discarded) can claim a refund. This procedure shifts the burden of proof from the administration to the polluter. In some cases, insurance markets can be created for assessing environmental hazards and can reduce the administrative burden of tighter environmental regulations.

5.50 The choice of instruments involves the question of who receives the benefits and who bears the costs of improved environmental policies, which is critical for the political acceptability of an environmental strategy. Often, the best strategy for the establishment of a market mechanism is to allocate property (or pollution) rights in proportion to previous resource use, as was done for the PM-10 compensation mechanism in the Santiago Region. This avoids the negative income effect that can otherwise result for previous resource users. The financial cost of increased environmental control can be reduced by phasing in control measures over an extended period of time. Political acceptability can be increased by applying policies consistently and predictably.

5.51 The EIA process introduced under the Basic Law is one of the critical instruments of environmental regulation and should be implemented such a way that it achieves effective environmental protection at the lowest possible cost. A promising instrument for making the EIA process more transparent and efficient is the application of shadow prices for environmental damages. One of the main criteria for evaluating an EIA would be whether the investment project is profitable after subtracting the environmental shadow costs. CONAMA would develop a shadow price list for environmental damage (i.e., a monetary amount per ton of each pollutant or each ha. of forest converted) from economic analysis (including studies of damage costs or abatement costs done for other countries as a first-order approximation). Ultimately, shadow prices should be regionally differentiated to reflect local conditions with different levels of damage costs.

5.52 Informal Policies. Evidence of voluntary compliance with environmental standards in many countries, including Chile, suggests that improved environmental management does not depend on formal regulation and its enforcement alone. The public release of information on pollution and environmental management by firms often provides a powerful incentive for pollution abatement. The prominent publication of pollution inventories and forest management plans, within legal limits, should be used as an instrument of informal environmental policy. Similarly, an informal role of NGOs or business associations in certifying environmental standards should be encouraged.

5.53 Environmental Liability. The Basic Law creates the basis for legal liability of polluters for the environmental damage of pollution. Ex-post liability for environmental damage, as opposed to ex-ante regulation of pollution, can become a very powerful instrument for improved environmental management and shifts some responsibility for improved environmental management to the legal system. The risk of liability claims would create an incentive for the reduction of environmental damages. It can be expected that a market for liability insurance will develop. The incentive for pollution abatement would then work through reduced insurance premia for a reduced likelihood or magnitude of environmental damage. Due to limited experience with environmental liability in Chile and the information requirements for environmental lawsuits, environmental liability should be seen as supplementary to other instruments of environmental policy. Training and capacity building in the legal system will be required to make environmental liability an effective policy instrument in practice.

Improving Environmental Information and Management Capabilities

5.54 Integrated environmental management that is based on the comparison of costs and benefits of improvements in environmental quality depends on the availability of data. Unfortunately, the information base for environmental management in Chile is still weak. Sectoral data collection focussed on production aspects and neglected environmental information. To address this weakness, the Bank's Environmental Institutions Development Project supports the creation of a National Environmental Information System within CONAMA. This includes the assessment and coordination of information sources within the existing agencies with sectoral responsibility as well as the collection of new data. Work is underway on the design of a comprehensive environmental information system which will first be tested in three pilot regions. As a principle, all environmental data should be available to the public.

5.55 There is an urgent need to improve the availability of environmental information and the capacity for systematic analysis of environmental problems. Information gaps are particularly severe in the areas of hazardous and toxic wastes, pollution from small scale mining enterprises, and native forest management. The Environmental Institutions Development Project contains a component for training and education on environmental management for government staff as well as the general public. The development of capacity to evaluate environmental problems in the private and the public sector should have high priority. The three sector chapters of this report provide examples of the type of environmental analysis that needs to be conducted for other urgent problems, such as pollution from the mining sector.

Investments and Financing

5.56 International experience suggests that, if environmental controls are prudently phased in, the additional costs form only a small part of total production costs for most industries. Nevertheless, significant investments are necessary to address the environmental problems of the country. Environmental control investments under consideration include sewage treatment plants, improved mass transit, and pollution abatement plans for the mining industry. Some investments will be undertaken by the private sector in response to changes in economic incentives as a result of policy and regulatory changes. Other investments will have to be undertaken by publicly owned enterprises (e.g., abatement measures in the public mining companies, sewage treatment where local companies are publicly owned). These costs can be recovered from the users of sewage and related services but ultimately come from government budgets where output prices are set by international markets, i.e. in the public sector mining companies.

5.57 In specific cases, the existence of market failures or short-run liquidity constraints may justify government support for environmental control investments by the private sector. For example, in the case of agricultural small holders with limited access to credit or poor households with high discount rates, there can be a justification for public support of small-scale environmental investments in energy efficiency, soil stabilization, and similar measures. Also, in the introduction phase of tighter environmental controls, tax benefits and special credit facilities can be used to speed up the adjustment in the private sector and assist especially small companies in meeting their increased financing needs.

5.58 Government functions include the collection and dissemination of environmental information, monitoring environmental quality, as well as the management and enforcement of environmental regulations. Significant additional resources will be required by government agencies for improved environmental management and enforcement of regulation. In many cases, user fees can cover the additional costs of an improved environmental administration system. Earmarking a share of the penalties assessed for noncompliance with environmental regulation for the budget of the enforcement agencies can create effective incentives within the public sector for improved enforcement. Finally, several bilateral and multilateral agencies are willing to provide financial support for investments for improved environmental management.

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ANNEX 1: Summary Country Data

Population	13.6 million (85 percent urban)
Life Expectancy at Birth	72 years
Literacy	93 percent
Area	757,000 km^2
GNP/capita	$2,730
PPP-GNP/capita	$8,090
Annual GNP growth 1980-92	3.7 percent
Merchandise Exports	37 percent of GDP (47 percent mining, mostly copper, 40 percent industry including processed timber and fish products, 12 percent agriculture)
Govt. Budget Surplus	2.4 percent of GNP
External Debt	148 percent of exports; 49 percent of GNP
External Debt Service	21 percent of exports
Administrative Structure	Regions I - XII, numbered from north to south, plus Santiago Metropolitan Region

Source: World Bank, World Development Indicators 1994, Banco de Chile.
All data for 1992.

ANNEX 2: Summary of the Environmental Institutions Development Project

Project Objectives

The central project objective is to assist the Government in implementing sectoral policies and plans aimed at:

(i) Establishing an institutional framework to manage environmental protection and conservation of natural resource activities by:
   (a) strengthening the technical and administrative structure, and financial management capacity of the Technical Administrative Secretariat (STyA, now CONAMA);
   (b) putting into effect and updating the legal regulatory framework for environment;
   (c) incorporating environmental assessments in public and private sector investment projects;
   (d) providing training in environmental and natural resources management;
   (e) developing a nonformal education program;
   (f) implementing small environmental projects at the community level;
   (g) developing economic analysis of environmental issues; and

(ii) strengthening priority sectors engaged in environmental activities by:
   (a) improving the quality of management and conservation of Chile's native forest;
   (b) implementing several studies leading to a national industrial anti-pollution strategy;
   (c) supporting ongoing mining sector initiatives to reduce the negative impact of mining activities on the environment.

Project Description

The project would support the above objectives by financing two components to:

(i) Establish the Institutional Framework to Manage Environmental Protection and Conservation of Natural Resources (76 percent of total project cost) by:
   (a) providing about 890 staffmonths of technical assistance to strengthen the institutional and financial management capacity of the STyA;
   (b) hiring 87 professionals and 40 administrative personnel to develop STyA at the central and regional levels, as well as environmental ministerial units;
   (c) implementing a national training program for about 6,550 participants in environmental and natural resources-related subjects;

- (d) implementing community based workshops on environmental issues for about 11,700 people;
- (e) providing study tours and fellowships abroad for about 90 professionals;
- (f) developing and distributing about 6,550 sets of teaching materials and books;
- (g) implementing 34 studies in sectoral environmental issues;
- (h) implementing about 30 environmental improvement, community-based projects; and
- (i) providing office space, data processing, vehicles and communications equipment, office supply and maintenance for STyA headquarters and regional offices.

(ii) Support priority Sectors Engaged in Environmental Protection and Conservation of Natural Resources (24 percent of project cost) by:

- (a) providing about 260 staffmonths of technical assistance to carry out a forest and natural vegetation cadastre, a rapid air and hazardous waste pollution inventory in six regions, develop environmental norms and standards relating to effluent discharge, solid waste disposal, and mine abandonment;
- (b) implementing a training program for about 300 participants in: (i) native forest cadastre; (ii) rapid air and hazardous waste pollution; and (iii) effluent discharge, solid waste disposal, and mine abandonment;
- (c) implementing 12 studies to support natural vegetation, water pollution, industrial pollution policies, as well as the feasibility to recycle water for human consumption; and
- (d) providing office, data processing and communications equipment, software, and vehicles to implement the forest and natural resources cadastre.

ANNEX 3: Emission Factors, Base Case and Control Scenario

	Base Case	Control Strategy	Units
PM-10			
Gasoline Vehicles	0.06	0.01	g/km
Trucks	1.28	0.40	g/km
Buses	2.06	0.12	g/km
Point Sources	9.96	.29	kg/TOE
NO_x			
Gasoline Vehicles	1.70	0.66	g/km
Trucks	12.50	7.90	g/km
Buses	5.57	2.39	g/km
Point Sources	4.86	2.4	kg/TOE
VOC			
Tailpipe	3.52	0.52	g/km
Running Losses	0.58	0.16	g/km
Diurnal	24.67	2.58	g/day
Hot Soak	6.85	1.13	g/trip
Trucks	4.29	2.05	g/km
Buses	1.54	0.46	g/km
Point Sources	2.95	0.07	kg/TOE
SO_x			
Gasoline Vehicle	0.17	0.17	g/km
Trucks	3.82	0.38	g/km
Buses	2.64	0.00	g/km
Point Sources	0.03	2.64	kg/TOE

ANNEX 4: Comparison of Emission Inventory in Base Case and Control Strategy

	PM-10			NO_x			VOC			SO_x		
	Base Case Ton/Year	Control Ton/Year	Reduction %	Base Case Ton/Year	Control Ton/Year	Reduction %	Base Case Ton/Year	Control Ton/Year	Reduction %	Base Case Ton/Year	Control Ton/Year	Reduction %
Point Sources:												
Industrial Processes	608	608		568	568		17	17	2.4	2793	2800	0.3
Industrial Furnaces	2746	1570	42.8	2586	2273	12.1	445	89	85.9	11513	13120	-14.0
Heating Furnaces	358	230	35.8	214	192	6.6	23	6	74.4	922	989	-7.4
Bakeries	150	17	89.0	54	33	38.7	26	1	96.5	51	162	-216.6
Subtotal	3862	2424	37.2	3422	3073	10.2	511	87	83.1	15278	17072	-46.45
Mobil Sources:												
Private Cars	412	69	83.3	11662	4527	61.2	34242	5472	84.2	1194	1194	
Taxis	32	5	83.2	909	353	61.2	2668	426	84.2	93	93	
Buses	1861	108	94.2	5049	2166	57.1	1395	417	70.1	2392		100.0
Trucks	394	123	68.9	3849	2432	36.8	1413	631	55.3	1176	118	90.0
Subtotal	2698	306	88.7	21467	9479	55.8	39718	6947	82.5	4854	1404	71.1
Group Sources												
Gasoline Stations							1526	1526				
Residential Gas Burning				22	22		7	7				
Residential Log Burning							100	100		47	47	
Resident Kerosene Burning				40	40					158	158	
Dry Cleners							622	622				
Automobile Painters							529	529				
House Painters							3357	3357				
Residential Solvent Use							921	921				
Wood Formal Residential	486	486		68	68		583	583				
Wood, informal Residential	1021	1021		122	122		43	43				
Past, Paved Roads	11779	11779										
Dust, Unpaved Roads	5577	5577										
Subtotal	18862	18862		252	252		7688	7688		204	204	
TOTAL	25423	21592	15.1	25140	12804	49.1	47918	14721	69.3	20337	18680	8.15

ANNEX 5: Population Distribution

Table 1: Residential Distribution of Population by *Comuna*

No.	COMUNA	HABITANTES
1	Quilicura	40,659
2	Huechuraba	61,341
3	Conchalf	153,089
4	Renca	129,173
5	Pudahuel	136,642
6	Cerro Navia	154,973
7	Quinta Normal	115,964
8	Lo Prado	110,883
9	Independencia	77,539
10	Recoleta	162,964
11	Estaciòn Central	142,099
12	Vitacura	78,010
13	Las Condes	197,417
14	Lo Barnechea	48,615
15	Providencia	110,954
16	Santiago	202,010
17	La Reina	88,132
18	Ñuñoa	165,536
19	Maipú	257,426
20	Cerrillos	72,137
21	Pedro Aguirre Cerda	128,342
22	Lo Espejo	119,899
23	San Miguel	82,461
24	La Cisterna	94,732
25	San Joaquín	112,353
26	San Ramón	101,119
27	La Granja	126,038
28	Macul	125,535
29	Peñaloén	178,728
30	La Florida	334,366
31	Puente Alto	254,534

Table 2: Population distribution by grid cell (cell weights are row percent times column percent).

HABITANTES DE SANTIAGO DISTRIBUIDOS GEOGRAFICAMENTE Total: 4712146

240	563	651	726	1490	801	2883	574	1796	1122	0	0	0	4351	19650	1249	2020	0.8%
240	553	567	3723	14979	7941	41309	19261	21848	10025	167	5984	4212	4972	15957	6288	613	3.4%
240	582	997	1128	5812	12700	44586	70588	57373	8114	6175	20444	28401	13934	11505	2431	44	6.0%
240	591	3639	22086	50878	38738	37577	46725	39515	18852	14801	19409	35719	16319	6062	1111	148	7.5%
240	748	17699	77399	64470	32919	30368	40123	21817	21205	30900	22676	32319	25078	624	0	0	8.9%
240	651	27231	68188	78013	42585	27139	42725	33814	39419	36116	37166	19818	8811	1822	0	0	9.8%
198	316	4082	8983	24363	52581	34855	32405	45502	42770	26588	41663	36911	27928	1583	0	0	8.1%
120	428	2752	16933	33250	40129	36973	39059	39078	30185	40135	58813	35887	31855	218	0	0	8.6%
222	355	30043	26682	23636	10091	58465	41590	35440	41737	38838	25803	2692	164	364	0	0	7.1%
240	9544	50699	26386	17325	20762	79844	37301	43383	53528	41471	59374	19738	789	237	0	0	9.8%
36	1187	33841	4143	1339	20914	30672	37311	50514	55489	56373	35467	10962	1350	237	0	0	7.2%
2860	11531	9948	9246	729	4328	39590	51501	62041	48181	51236	42484	2905	995	0	0	0	7.2%
14025	18939	1870	4486	882	19682	44363	48846	34101	18985	26495	40328	5896	840	134	0	0	5.9%
1629	504	462	107	557	35090	46752	34248	30236	18919	22656	24664	3532	1547	516	778	4059	4.8%
240	204	198	0	1268	27799	19362	1687	2075	10135	18746	34228	16055	5937	6090	612	667	3.1%
240	222	300	144	1028	3978	2109	132	2325	6255	23659	29558	7418	1172	1661	0	0	1.7%
198	198	240	240	240	240	240	240	240	240	240	240	240	240	0	0	0	0.1%
0.5%	1.0%	3.9%	5.7%	6.8%	7.9%	12.2%	11.6%	11.1%	9.0%	9.2%	10.6%	5.6%	3.1%	1.4%	0.3%	0.2%	100

ANNEX 6: Formulas for LEV and TV

$$LEV = \max_{t} \frac{P(t) \cdot Q(t) - C_t}{e^{rt} - 1} - C_0 \qquad (7)$$

where,

P(t) is the stumpage value of a stand harvested at age t. This is the price of the products mixture at the market minus transport and harvest costs.

Q(t) is the volume of different products harvested at age t. This is actually the timber production function of the stand.

C_t is the sum of annual costs (capitalized at rotation age) incurred since after planting the trees until inmediatly before harvest age.
C_0 is the cost of planting the trees now.

$$TV = FH + FV \qquad (8)$$

where TV is the total forest and land value, including the first harvest value (FH). The forest (and land) value is calculated according to the expression:

$$FV = \max_{t,G} P_0 (S_0 - G_0) + \frac{P(t) \cdot [Q(t,G) - G]}{e^{rt} - 1} \qquad (9)$$

where,
P_0 is the stumpage price currently paid for the volume removed from tha forest.
P(t) is the stumpage value of trees harvested at year t.

S_0 is the current stock in the stand.

G_0 is the residual, or growing stock, left after harvest at age zero. For the selection harvest method. This stock will be higher than in other methods.

Q(t,G) is the volume to be harvested at year t when a growing stock of G was left in the previous harvest.

r is the discount rate.
t is the harvest cycle or rotation.

ANNEX 7: Estimated Growth Rates for Selected Forest Types in the Study Area

Forest Type	Subtype	Mean Annual Increment (MAI) m3/ha
Siempreverde	Olivillo SV Canelo regrowth Nadis	unknown; est. at 6-10 m3/ha between 4 and 14 m3/ha between 4.5 and 14 m3/ha unknown; est. 6 m3/ha or less
Coigue-Rauli-Tepa	mature forest regrowth	between 8 and 20 m3/ha between 5 and 18 m3/ha
Roble-Rauli-Coigue	altered forest original forest regrowth	between 5 and 10 m3/ha between 8 and 20 m3/ha between 5 and 18 m3/ha

Source: Paredes, 1994.

ANNEX 8:
Some Caveats on Tourism Expenditure Estimates

A. Information biases

1. The organism in charge of tourism related issues in Chile is SERNATUR. SERNATUR has no resources to perform its own data collection process and depends entirely upon the information and data collected by INE, the National Institute of Statistics. Currently INE is dedicated to the processing of the 1992 Census data and is far behind on its tourism and data collection and processing. The basic information used to estimate tourism related expenditures is the number of registrations in lodging facilities located in the X region. This piece of information presents the following problems as the basis for tourism expenditure estimates:

High non response rate of lodging facilities

2. INE sends questionnaires to inquire about basic tourism information such as lodging capacity (number of rooms and beds), total number of arrived passengers, number of pernoctations and passenger citizenship. An important problem is the high rate of non response detected for surveys sent to 'existent' lodging facilities[1]. During the 1989-91 period the average non response rate at the national level was 22%, and 35% for the January-June 1992 period. Disaggregated information at the regional level, indicate that this problem is particularly severe in regions VI, IX and X, with non response rates being as high as 70%, 79% and 69% respectively during the April-June 1992 period (INE, 1992)[2].

Double counting

3. The total number of registrations at lodging facilities is not equal to the number of visitors that registered one or more times at lodging facilities. Because there is no track about the average number of times a tourist registered at different lodging facilities during his stay in the region, double counting is an important problem. Data for the X region indicate that lodging facilities report that the average length of stay at lodging facilities was 1.9 for Chileans and 1.7 for Foreigners in 1992 (INE, 1992). Thus, by dividing the average length of stay in the region by the average length of stay at lodging

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1. `existent' means part of the universe as understood (and registered) by SERNATUR/INE. According to tourism specialists this universe would be an underestimate of the real universe because of the high informal lodging capacity in the X region.

2. Szmulewicz (1993) a tourism specialist from Universidad Austral de Chile confirmed the very low response rate of lodging facilities in the X region.

facilities we obtain an estimate of the average number of lodging facilities visited by an average tourist.

4. The adjustment factor would equal

- Foreigners : 7.19 days /1.7 days = 4.2 lodging facilities
- Chileans : 8.52 days/1.9 days = 4.5 lodging facilities

`Non registered' Tourists

5. Very limited information is available about informal lodging facilities such as schools that serve as dormitory during the summer time, local people who rent rooms during the summer, etc. This type of lodging would be particularly significant in the Xth region where there is a lot of juvenile tourism (backpacking, hiking, etc.). House renting, secondary residences and similar, is also a common modality during vacations particularly for family groups. No register is available of this kind of tourist so ever. Several tourism experts indicate that informal lodging is an important component of the total lodging capacity in the country and no register is available (Szmulewicz, 1993). Argentineans, for example, which are an important part of foreign tourists in the country, spend much less on average than other foreigners (see Table 2.3), and prefer camping, renting apartments or even sleeping in trucks (El Mercurio, 03/28/93).

6. A very gross indicator of the existence of these 'non registered' tourists, is the difference that exists in the case of foreign tourists, between those entering the region through terrestrial paths (located in the X region and on the boundary with Argentina) and those registering at lodging facilities in the X region[3]. According to 'Policía de Investigaciones de Chile' statistics, 79,542 foreigners entered the country through terrestrial paths located in the X region in 1990. If we assume that 67% of them are Argentineans[4], then a total of **53,293** Argentineans entered through this region. Obviously, not all the Argentineans that visited the X region entered through these paths. 40% of ALL foreigners that enter the country cross at a northern path, 'Los Libertadores', and it is very likely that some of them travel south and visit the X region.

7. Registration figures, on the other hand, indicate that only 20,525 Argentineans registered at lodging facilities in the X region. If we adjust this figure by the 69% non

3. It must be noted that entrance to the country data are more reliable because it is registered more accurately by International Police because of national security reasons.

4. 67% is the national average and is probably an underestimation for the X region which has an important influx of Argentinean tourists during the Summer time.

response rate and by the 4.2 double counting factor[5], it results in **15,764** Argentinean visitors (number of individuals).

8. The difference between the visitors to lodging facilities in the X region and those crossing the border is 37,529 persons. Thus, 70% of those Argentineans crossing the borders in the X region do not appear registered at ANY lodging facility in the X region.

9. No information is available for the number of Chileans staying at informal lodging facilities. The only relevant information available, is Szmulewicz (1993) communication, that in his opinion the lodging capacity of the X region is at least 15% higher the one assumed by SERNATUR/INE.

Foreigners and Tax evasion

10. Another source of problems is that apparently hotels surveyed by SERNATUR tend to underreport their income and pay less taxes. Tax evasion seems to be an issue in the tourism sector. The main source apparently being the non reporting of income associated to foreign tourist visits, for example, in the case of organized tours from other countries (Szmulewicz, 1993). However, no indication of the magnitude of this problem is available.

B. Adjustment of the 1990 tourism expenditure figure

i) Double counting
Divide the number of registered people at lodging facilities by 4.2 and 4.5 in the case of Foreigners and Chileans respectively. For 1990,

- Foreigners : 70,510 : 4.2 = 16,788 visitors
- Chileans : 459,406 : 4.5 = 102,090 visitors

ii) Non response rate of lodging facilities
The reported non response rate for the lodging facilities in the Xth region was 69% on average during 1992. Which means that if the lodging facilities answering the questionnaire are representative in terms of registrations and average stay, one should adjust by this non response factor.

5. The 69% non response rate refers to the fact that 69% of the surveyed lodging facilities do not answer the surveys. The 4.2 double counting factor refers to the number of lodging facilities visited by each tourist on average during their stay in the region (see points 1 and 2 above).

- Foreigners : 16,788 visitors x 100/31 = 54,155 visitors
- Chileans : 102,090 visitors x 100/31 = 329,323 visitors

iii) Informal lodging facilities
Based on the difference among registered Argentineans and those crossing the borders, 70% do not register at any lodging facility. We will assume for all Foreigners and Chileans as well, that **only one third** of this 70% effectively do not register at any lodging facility, that is 23%. An additional assumption is that these tourists spend 50% less on average than a 'formal' tourist. This means an average expenditure of US$ 22.05/day for Foreigners and US$ 12.5/day for Chileans.

- Foreigners :

54,155 visitors x US$ 44/day x 7.19 days
54,155 visitors x 23% x (US$44/day x 50%) x 7.19 days

US$ 19,102,710

- Chileans :

329,323 vis x US$ 25/day x 8.52 days
329,323 vis x 23% x (US$25/day x 50%) x 8.52 days

US$ 78,212,566

TOTAL : US$ 97,315,276

Table 1
Comparison of Tourism expenditure estimates

	Original estimates (see Section II)		Adjusted estimates (see Annex I)	
	No. registrations	Tourism expenditure estimate	No. visitors	'Adjusted' tourism expenditure estimate (US$ thousand)
Chileans	459,406	97,853.5	405,067	78,212.6
Foreigners	70,510	26,607.3	66,611	19,102.7

11. Table 1 summarizes the result of incorporating all the data problems mentioned in points 1-3. The resulting total visitor and tourism expenditure figures are lower by approx. 11% and 22% respectively.

12. Additional information though indicates that these 'adjusted' estimates would be a bottom line for the contribution of the Xth region in terms of tourism. According to 1990 estimates of foreign currency generated by foreign tourists in the country, 976,391 tourists generated 'exports' for US$ 539.7 million. Now, how much is attributable to the X region? In 1990, the X region contributed with 15% of the total number of beds in the country, 9.4% of total pernoctations in the country, and 4% of private investment in tourism in the country. Thus, at the gross level **at least** US$ 21.6 million should be attributable to the X region, which is higher than our 'corrected' expenditure estimate. The upper level being US$ 81 million for the X region (15% of US$ 539.7 million).

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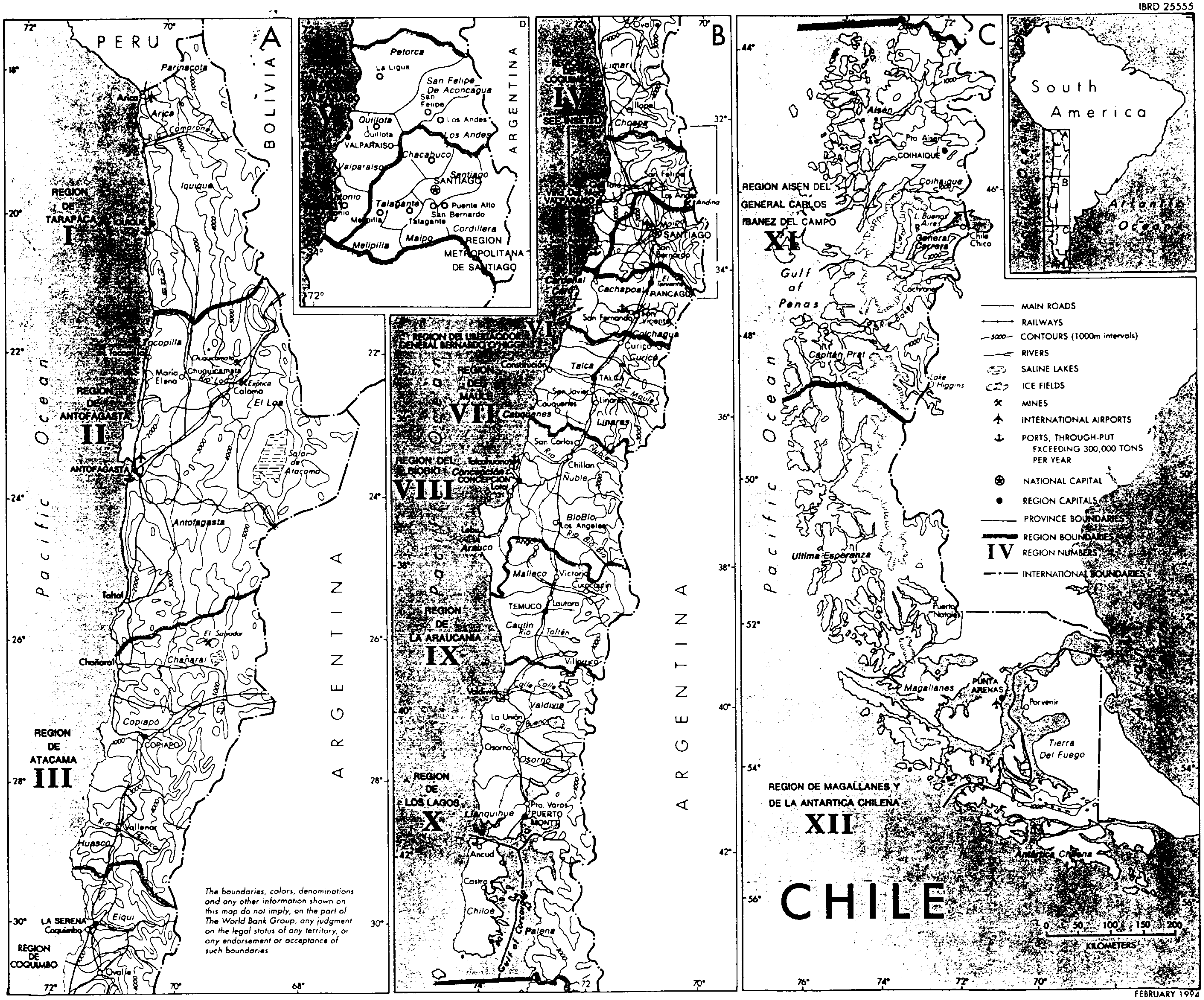

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