Renewable Resource-Based Alternatives to Coca Production 4

The geography and topography of the Andean region provide diverse ecological settings with a broad range of natural renewable resources. Developing and implementing sustainable management of these renewable resources could help improve food and fiber production for national consumption and for export markets. Today, agricultural, forest, wildland and wildlife, and aquatic resources are all exploited to some extent. However, use of improved production and management technologies could expand these activities and generate increased economic benefits. In terms of coca substitution programs, greatest attention has been given to agriculture and some promising crops and cropping systems.

INTRODUCTION

Agroecosystems in the Andean coca-producing regions differ markedly from the highly mechanized lowland agriculture practiced, for example, on the great plains of North America. Rather, agriculture tends to be small-scale and distant from markets or political or financial support, and extremes of topography preclude extensive mechanization in most cases. The small returns for most farmers impede acceptance of new and potentially risky technology. High-input approaches to farming, characterized by the green revolution, are less applicable in these settings.

Moreover, the diversity of Andean environments does not favor regional agricultural and agronomic planning. For example, almost 50 percent of Bolivian and Peruvian land area is steep slopes and highlands. Only about 10 percent of the total surface area of each country is suitable for row crop agriculture. Frequent floods, droughts, and severe soil erosion make agricultural production difficult in many areas.


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The most fertile agricultural soils are alluvial deposits in the valleys. Physical environmental features (e.g., soils, slope, erosion potential) can change character markedly over short distances. Climatic features (e.g., precipitation patterns, winds, temperature) may vary with distances (especially altitudes) and time (season). This variability means that a site-specific approach must be applied to defining realistic technical solutions for coca substitution. Unfortunately, little site-specific information exists on climate, soils, or topography for some parts of the Andes and the prospects are minimal for gaining this information in certain coca producing areas (e.g., Alto Huallaga).

Intricate patterns of land uses and land tenure have evolved over the years as a result of disparate cultural forces. Current agriculture in the region is a mixture of pre-Columbian, Spanish, and contemporary practices, many of which are incompatible with one another. This situation further complicates development of alternative crops and cropping systems. Nevertheless, significant efforts have been invested in identifying crops and crop combinations that might improve the value of agricultural activities in the Andean region. Largely, these efforts have focused on export agriculture rather than enhancement of the domestic food supply system. Difficulties in moving these commodities to the international market, as well as in providing sufficient quantity and quality of product, have constrained alternative crop efforts to date.

In addition to agricultural resources, forest, aquatic, and wildlife resource exploitation could offer alternative livelihoods. Tropical forest resources have received increased global attention over the last several decades. Tropical timber exports were key in national economies in the mid- 1900s and continue to command high prices in the international market. Constraints to continued or increased exploitation largely arise from concerns over conservation of biological diversity and potential adverse global environmental effects. Indeed, consumer boycotts of tropical

Simple processing and storage requirements make cocoa (Theobroma cacao) *an attractive alternative in remote areas. Shown here is cocoa production in the Alto Beni, Bolivia.*

hardwoods for these reasons are becoming more common. Nevertheless, there are opportunities for sustainable timber production and forest conservation and protection in the Andean region (71).

Tropical wildlife has been an important domestic and export resource in South America for at least 400 years (70,72) and has been economically important. Unsustainable exploitation, however, increased concerns over species loss and led to international treaties and trade agreements to protect rare, threatened, and endangered species (i.e., Convention on International Trade in Endangered Species). More recently, international conservation organizations have focused on sustainable development of wildlife resources. Potential markets include hides and fibers, pet, meat, and other animal products (e.g., bone), and technologies exist for managing a variety of amphibians, reptiles, fishes, birds, and mammals to provide these commodities. Nature-based tourism associated with protection and conservation of wildlife and wildland resources offers another opportunity for increasing economic returns from conservation activities (6).

Freshwater aquatic resources, largely fisheries in lakes, rivers, and streams, currently occupy a small share of national food production systems.

Estimates suggest that current harvest is far below optimum sustainable yield for many species. A paucity of data on the extent of Andean freshwater resources hinders analysis of the potential contribution they could make to national food production and economies. Yet, use of improved postharvest handling, storage, and transportation of fishery products alone could increase their contribution. Additional opportunities lie in implementation of improved capture, resource restoration, and aquiculture technologies (101).

Opportunities exist for improving crop substitution programs and increasing their acceptability to local populations. Some crops, production and processing technologies, and markets are available. New crops that might improve the economics of agricultural production have been identified. However, further research will be needed to identify appropriate cultivars, production techniques, and market potential. If substitution programs expand the range of resources exploited, sustainable development technologies for forest, wildland and wildlife, and aquatic resources will be needed.

Table 4-l-Temperature and Rainfall of Major Coca Production Zones

	Mean annual temperature (C)	Rainfall (mm)
Bolivia		
Chapare	23-25	2,500-5,000
Colombia		
Amazon[a]	22-26	2,500-5,000
coffee belt	20-24	1,000-1,900
Peru		
Alto Huallaga	22-26	2,500-3,500
Central Hullaga	21-25	1,400-1,900
Central Urubamba	21-25	2,000-2,500
Ene	23-25	1,700-1,900
Gran Pajonal	21-25	1,700-1,900
La Convention	22-24	n.d.
Mayo	21-25	n.d.
Pachitea[a]	23-25	2,000-3,500
Palcazu[a]	23-25	4,000-8,000
Pichis[a]	23-25	2,500-3,500
Tambo	23-25	1,700-1,900
Yurimaguas[a]	23-25	2,000-2,500

a Little diurnal temperature variation.
n.d. = no data.

SOURCE: H. Villachica, C. Lescano, J. Lazarte, and V. Chumbe, "Estudio de oportunidades de inversion en desarrollo e industrializacion de cultivos tropicales en Pucallpa," Perfil de proyecto para la planta de coloantes naturales yu para la planta de conservas de palmito, Convenio FUNDEAGRO, Region Ucayali, Lima Peru, 1992.

AGRICULTURAL RESOURCES

Coca is grown mostly in the humid tropic regions of the Andean countries of Bolivia, Peru, and Colombia. While little variation in temperature is evident among the coca growing zones, precipitation variation is obvious (table 4- 1). The difficulties faced by agriculture in such areas are well known (49,55,98). Many problems are related directly to high rainfall and temperature regimes that promote nutrient leaching, poor soil composition, low fertility, and rapid growth of pest problems. All of these features can lead to increasing dependence on external inputs (e.g., pesticides, fertilizers, fuels) and affect the types of agricultural opportunities available to farmers.

Distinct changes in the agricultural sector resulting from the expansion of the cocaine economy complicate efforts to improve agricultural profitability. As production of coca leaf became agronomically and economically attrac-

[1]This section was drawn largely from the following contracted background papers:

H. Villachica, "Crop Diversification in Bolivia, Colombia, and Peru: Potential to Enhance Agricultural Production," contractor report prepared for the Office of Technology Assessment, April 1992.

S. Gliessman, "Diversification and Multiple Cropping as a Basis for Agricultural Alternatives in Coca Producing Regions," contractor report prepared for the Office of Technology Assessment, February 1992.

B. McD. Stevenson, "Post-Harvest Technologies to Improve Agricultural Profitability," contractor report prepared for the Office of Technology Assessment, March 1992.

A. Chavez, "Andean Agricultural Research and Extension Systems and Technology Transfer Activities: Potential Mechanisms To Enhance Crop Substitution Efforts in Bolivia, Colombia, and Peru," contractor report prepared for the Office of Technology Assessment, December 1991.

tive, many farmers abandoned livestock raising and other crop production systems. Some local traditional agriculture systems were abandoned as well. Larger areas were deforested, more coca planted, and less time and energy were invested in traditional agriculture. This increasingly affluent agricultural sector developed a dependence on imported purchased food and experienced a shift in aspirations.

While the agricultural sectors in Bolivia, Peru, and Colombia are diverse, some similarities among producers and farm size are evident in primary coca producing regions. Producers tend to be semi-commercial (i.e., producing subsistence crops along with some cash crops including coca), production units are small (e.g., 20 hectare units or less are common); and production systems tend to be labor intensive. The remote nature of the producing zones means that inputs maybe costly and difficult to obtain and markets (other than at the "farm-gate") are difficult to reach. Coca plays a key role in farm income.

Crop substitution strategies must work on two fronts. Development of new production options for the coca producing regions must be complemented by development in areas from which migrant coca growers and laborers come. National and international assistance and research organizations support efforts to identify and expand opportunities for new crops that can replace coca in the agricultural economy (105). Primary categories through which agricultural profitability might be increased in the coca growing regions of the Andean nations include:

- Diversifying production,
- Intensifying production,
- Improving production efficiency, and
- Increasing the value of products through processing (chapter 5).

Current crop substitution efforts focus on diversifying production by incorporating high value crops. However, attention is being given increasingly to the latter categories.

Despite the potential for improving production through innovative cropping systems, the acceptability to producers comprises an important concern. Social and economic advantages must accompany improved systems. Crop diversification, increased market options, reductions in direct costs and risks, and increased opportunities for involvement for all members of the family or community become critical components of acceptable alternative systems.

Diversifying Agricultural Production

Diversifying agricultural production by incorporating high-value crops into production systems offers one approach to expand alternatives for agricultural populations and allows an incremental evolution from a coca-based production system to one based on legitimate markets. Indeed, this approach is the basis of traditional crop substitution efforts, and ongoing research focuses on identifyng high-value traditional and nontraditional crops suitable to local agricultural production systems.

Inherent in the diversification strategy is the ability of farmers to continue to provide for their basic needs during the development stage of the new production system. For example, many cropping systems require 3 to 5 years of effort prior to realization of profit (105,122). Coca could be maintained as a cash source during this period although it seems counter to substitution program goals. However, such an approach could offer an alternative to costly agricultural subsidies.

Research has focused on a variety of crops that could be suitable for local, regional, national, and international markets. Largely this research is market driven and focuses on grains, industrial crops, fruits and nuts, and spices. Blending of these crops into traditional food production systems is another important feature of these efforts. In this way, producers continue to provide for basic food and fiber needs while developing opportunities to generate cash through marketing.

Table 4-2—Cropping Patterns of the Chapare, Bolivia

Crop	Hectares (thousands)	Percent	Percent of total
Annuals			
Corn	3.3	9.00/0	2.7%
Rice	20.0	54.3	16.8
Yuca	13.3	36.1	11.2
Perennials			
Banana	19.8	24.0	16.6
Citrus	6.5	7.9	5.46
Coca	55.9	67.8	46.9
Other	0.3	0.3	2.5

SOURCE: Development Alternatives, Inc., "Environmental Assessment of the Chapare Regional Development Project, Bolivia, " DAI, Bethesda, MD, 1990, In: Stevenson, 1992.

The range of potential commodities that could offer agricultural alternatives is restricted to a certain extent by the environmental features of coca growing areas. Box 4-A describes some crops identified as potential alternatives. Although the list is not exhaustive, it illustrates the range of crop types that might be considered and blended into existing production systems,

Most crop substitution strategies in the Chapare region of Bolivia involve some combination of soil-conserving perennial crops and annual cash crops for immediate returns (table 4-2). Research in annual crops concentrates on maize, rice, beans, and yuca; the perennials program is focused on citrus, coffee, cocoa, and pepper. Other research deals with production and management of cattle, pigs, and poultry.

Efforts are also underway to examine essential oils (e.g., eucalyptus, pyrethrum oils); natural plant chemicals (e.g., xanthophyll); spices (e.g., *piper nigrum);* tropical fruits (e.g., pineapple, passionfruit, bananas, carambola); and nuts (e.g., macadamia). Pineapples and bananas seem to be promising in terms of fresh export and there has been some success with shipments to Argentina and northern Chile. Nontraditional crops of turmeric *(Curcuma domestica)* and ginger *(Zingiber officinale)* demonstrate export potential and production is underway at a trial level. Several other

Pineapple is being produced as an alternative crop in the Chapare, Bolivia. Private sector investment in a local processing facility for Chapare and Santa Cruz pineapples may promote the value of production.

crops from the areas may have potential for increased profitability, including garlic, onions, peanuts, anise, cumin, and perennial fruit crops. Although export potential for many of these crops is low, improved postharvest practices could contribute to higher quality and greater economic returns.

A number of agricultural products are being industrialized, including: tea, banana, kudzu, yuca, mint, and lemon grass. In addition, a coffee production and processing industry is being developed in the Chapare. The scale of existing production and the 5-year potential for production increases for these crops are shown in table 4-3. Achieving this potential will require investment in producing plant material, promoting the crops

Box 4-A–Alternative Crops

Alternative crop research poses an immense problem because of the numerous, and sometimes competing, requirements associated with identifying legitimate crops that can compete with a "black market" activity. Not only must crops be suitable to agroecological conditions, they must possess qualities that make them socioculturally acceptable and economically attractive. This is a tail order for any research activity. Research in the Andean countries has focused on annual grain crops, industrial crops, commercial fruits, nuts, and specialty crops (e.g., spices, fibers, dyes). The following briefly describes some of these crops.

Annatto (*Bixa orellana*): Annatto (also Achiote) is a native plant from the Amazon region. The plant chemical bixin is extracted from the seeds and has commercial value as a natural dye. Peru currently supplies 40 percent of the international bixin market. Substitution efforts in Bolivia have begun to work on increasing Annatto production. Primary production concerns include the highly variable yields and bixin content of seeds (2.5 to 3 percent), appropriate planting densities, difficulties in blending annatto with other crops because of its fast-growing nature (although some success has been noted in annatto/cowpea combinations), and high hand labor requirements. Piant breeding efforts are focusing on increasing yields and the bixin content of seeds (up to 4 percent) and developing cultivars suitable to low-fertility, acid soils. High hand labor requirements might be addressed through harvest and threshing mechanization. Improved processing techniques could provide products with higher bixin content (increasing from 30 to 35 percent to 90 to 95 percent). The trend toward natural dyes may increase market opportunities for annatto production. Annatto seems to be relatively free of pests and disease problems.

Araza (*Eugenia stipitata*): Araza is a tropical fruit tree native to the Amazon region, although it is not yet widely cultivated. While the tree is tolerant of acid, low-fertility soils, best production is observed in well-managed and property fertilized fields. Primary production concerns include the relative lack of agronomic technology for cultivation, planting densities and field management to obtain optimum production, and fertilizer requirements. Improved production techniques, including promising ecotypes and associated nursery and field management needs, are current research areas. Fruit production begins 1 year after transplanting with final height reached by 6to 7 years, although this is affected by soil fertility. Araza's slow growth rate allows intercropping with crops such as cassava or turmeric, thereby generating benefits during the field development stage. However, there is no international market for araza currently. The high acid content precludes fresh consumption but it can be used for juice, dried fruit, and ice cream flavoring.

Bananas (*Musa sp.*): Bananas currently are produced in coca-growing zones and some success with export has been noted in Bolivia. Banana is a traditional crop in the Andean region and thus adoption is nota key concern. Further, since farmers already are familiar with banana production they could be more responsive to extension efforts to improve production. Primary production concerns include need for evenly distributed rainfall, high sunlight requirements, fertilizer requirements, need for iow wind conditions, and soil condition (deep with high organic matter content). Research is needed on improved varieties to enter export markets, appropriate planting densities, improved propagule selection, careful field management (e.g., weeding and thinning) to sustain production, and postharvest technologies. A number of pests and diseases affect bananas; however, chemical and management techniques exist to control the most devastating of these.

Black Pepper (*Piper nigrum*): Black pepper is being cultivated to some extent in or near coca-growing regions in the Andean countries. Pepper is a climbing shrub and requires a support to grow on. Either posts or trees may be used as supports and production techniques exist for both systems. National research institutes are working to improve production technology, and potential exists for technology transfer from current producing countries. Key needs include improved cultivars (for increased yield and pest resistance), propagation, and seedling management. Production concerns include field preparation, soil condition (e.g., well-drained, aerated, high organic matter content), fertilizer needs, and high labor requirements during establishment and harvest phases. Systems have been developed that intercrop pepper with ginger or cassava during the early growth stages, and additional work in China indicates potential for pepper, rubber, and tea systems. Primary pests include fungi and nematodes and while chemical controts are available, they are costly. Despite high labor requirements for production, primary processing is relatively simple and generally involves sun-drying and threshing.

Brazil nut (***Bertholletia excelsa***)**:** Brazil nut trees are not found in most coca-growing zones and a somewhat iengthydeveiopment period may hinder plantation development. Under cultivated conditions, nut production may begin in 8 to 10 years after planting or if trees are grafted this may be shortened to6 years. Production concerns largely center on the need for well-drained soils and the lengthy period from initialization to production. Brazilian researchers have developed techniques for brazil nut production and cropping systems. Further work conducted in Peru indicates some potential for mixed systems of brazil nut, cassava, rice, and tahiti lime. In fact, intercropping with other fruit trees may increase nut production by maintaining pollinator populations during the time the nut tree is not flowering. Testing is still in initial stages and there are no accurate estimations of potential income. Areas where the tree currently exists and coca is expanding, or areas where it is likely to expand, may provide the best possibilities for introducing this type of production system.

Cardamom (***Elettaria cadamomum***)**:** Cardamom, a high-value spice, is not native to the Andean region, although it has been identified as a potential alternative crop. Shade is important for cardamom growth but the plant will produce in poorly drained soil. This combination may offer an opportunity for farmers to crop some of their lower quality production areas. Propagation by rhizome allows cardamom production within 3 years, butthe susceptibility of rhizomes to mosaic virus detracts from this approach. Seed is being used increasingly, however, development time increases to 5 years and seeds iose their viability quickly. Cardamom has been incorporated in some Colombian cropping systems in an effort to diversify coffee and it is being introduced in Bolivia and Peru. Constraints to expansion include the lack of a local market and that the international market currentiy is satisfied by Asian and Central American production.

Citrus (Orange, Mandarin, **Tangelos):** Citrus production requires rather specific soil and climatic conditions. However, it is suitable for the Chapare, Aito Huallaga, Upper Mayo, and Coiombianpiedmont. Orange production largely would be directed to the juice market, while mandarin and tangelo production have potential for fresh markets. intercropping systems incorporating citrus are used widely in current production areas. Primary production concerns include soii conditions (e.g., well-aerated, deep soils), market size, and processing options for small communities. Pests and diseases are well known—ants, aphids, fruit fries, root rot, tristeza, and exocortis. Tolerant varieties are available and other management methods exist to prevent viral infections.

Cocoa (*Theobroma cacao*)**:** Cocoa is cultivated in coca-growing areas of Peru and, to a lesser extent, in Colombia and Bolivia. Research undertaken in Colombia, Brazil, Ecuador, and Costa Rica has focused on improved cultivars, nursery management, planting densities, cropping systems, agrichemical needs, and postharvest processing. Additional research needs include: matching varieties to ecological zones, seed production and availability, shade management for new fields, and intercropping systems for cocoa and other subsistence or economic crops. Evenly distributed rainfall and soii pH factors are primary production concerns for cocoa. Coma is affected by several diseases—witches broom, black pod, and monilia. Cultivation and harvest practices can combat witches broom and black pod infestation (i.e., tree pruning, frequent harvest), while monilia currently is oniy controlled through pesticide applications.

Coffee (***Coffea arabica***)**:** Coffee seems toofferthe closest economic alternative to coca in some regions and production methods and cultivars exist for shade and sun coffee. However, coca-growing regions that do not experience sufficient diurnal temperature variation may not be suitable since coffee requires such shifts for ripening. Primary production concerns include soii drainage, nursery management, and pest- and temperature-resistant cultivars. Coffee is affected by a number of pests and diseases (e.g., insects, nematodes, fungi), although

(continued on next page)

Box 4-A-Continued

the cherry borer and yellow rust pose the primary problems. Pesticides and tolerant varieties are available to reduce the adverse impact of pest infestations on production. Research supported by the Colombian National Coffee Growers Association (NCGA) has contributed significantly to salving a number of production problems.

Macadamia (*Macadamia integrifolia* and *Macadamia tetraphylla*): Macadamia production typically requires well-drained fertile soils with high organic matter content. Low temperatures can reduce nut production and the tree is very susceptible to freezing. This aspect may pose some difficulty for expansion in the Chapare, where seasonal winds can bring temperatures as low as 6 degrees C. Production concerns focus on the need for appropriate fertilizer regimes to sustain production. Current low grafting success (i.e., only 15 to 20 percent) has hindered expansion in Bolivia and Peru, although efforts are ongoing to promote macadamia production. The tree is suitable for interplanting with annual crops or coffee or other trees during early years and thus could be integrated in existing production systems. Pests and diseases that attack macadamia include the bee, ants, nut borers, rats, root diseases, and fungi; yet control measures are available, although in some cases expensive. Interest in production is increasing because of ongoing substitution programs. However, market is largely international and thus will require concomitant infrastructure development.

Passion fruit (*Passiflora edulis*): Passion fruit is a fast growing tropical vine and fruit production may begin as early as 8 to 10 months after transplanting from the nursery. While two varieties exist, the *flavicarpa* variety seems to be more suitable to the temperature conditions of the Andean region. Seed production is prolific and thus does not pose a constraint to increased production. The fast growth rate, however, affects passion fruit's suitability for intercropping systems, although it may be associated with short-season cassava, turmeric, pineapple, or as a nurse species for establishing another crop. Primary production concerns include high cost of posts to allow the vine to climb, pruning and fertilizing to sustain production, and need for hand labor. Insects and worms are the primary pests although control measures have been identified. Fungal pathogens can be controlled by appropriate field management that ensures good soil drainage. Although internal and external market conditions are good, improved field management techniques and harvest and processing opportunities could increase the profitability of passion fruit production.

Peach palm (*Bactris gassipaes*): Peach palm is native in many of the coca-growing regions of the Andean countries. The tree is cultivated for fruit and palm heart with the latter being more economically attractive. Primary production concerns include need for wail-distributed rainfall and dry periods, fertilizers, and near access to processing facilities. Harvests can be made within 18 to 20 months after planting. The palm has a high rate of sucker production allowing for 3 to 4 harvests per year. Instituto Nacional de Investigación Agraria y Agroindustrial (INIAA) in Peru has been working on production technology since 1985, including seedling types, transplanting techniques, and appropriate planting densities. Peach palm can be integrated with other crops at tower densities, but shading by the palm may preclude certain species; cassava can be planted prior to the palm to provide shade and income until the palm outshades it. Few problems with pests or diseases are noted and currently most can be controlled through good field management efforts (e.g., cultivation). Peach palm has been identified as one of the most promising alternative crops. However, efforts would be needed to expand the currently small world market for palm hearts.

Pineapple (*Ananas comosus*): Traditional pineapple production is largely dependent on hand labor and although traditional varieties tend to have low yields, fields may produce for 6 to 10 years. Improved yield cultivars have been developed, however the production period length is shortened significantly (Le., 11/2 to 3 years). Production concerns include improved cultivars (smooth cayenne), planting densities, fertilizer programs, soil preparation, and flower induction to increase yield and speed time to first harvest The shallow rooting system makes pineapple extremely susceptible to competition and higher planting densities make it difficult to intercrop successfully. Numerous pests and diseases affect pineapple production, although chemical and cultural controls exist. Some of these problems maybe reduced by using traditional varieties resistant to fungi although there is a trade-off with yields.

Rice (*Oryza sativa*): Increased rice production opportunities largely lie in import substitution. Research has identified high-yielding cultivars for certain production systems (e.g., alluvial and flooded systems), although varieties appropriate to upland coca zones are scarce. Primary production concerns include agrichemical requirements, field preparation (e.g., land bevelling which is costly and if done improperly can pose problems for water management), improved water management, and equipment. Fungal diseases pose the largest pest problems for rice production, and fungicides to treat these diseases are costly. Development of disease-resistant varieties could improve opportunities for expanded rice production.

Silk: Mulberry/silk production systems are being promoted in Colombia as an alternative to coca. Production technologies are well-known and easily available and technical assistance and credit opportunities exist for silk production in Colombia. Primary production concerns include the susceptibility of silkworms to agrichemicals requiring an organic production approach, establishment of "casetas" to house the silkworms, and availability of transportation to processing sites. Silk markets are well-established and, with quality cocoons, should be open to Andean production.

SOURCE: H. Villachica, "Crop Diversification in Bolivia, Colombia, and Peru: Potential to Enhance Agricultural Production," contractor report prepared for the Office of Technology Assessment, April 1992. P. Conway, "Silk For Life—Project Proposal," Silk for Life, Madison, Wisconsin, January 1991.

through extension programs, establishing post-harvest and marketing infrastructure, increasing availability of credit and private investment, and expanding market opportunities through product promotion in local and foreign markets (105).

Instituto Boliviano de Tecnología Agropecuaria—Chapare (IBTA-Chapare) research focuses on identifying profitable agricultural options suitable to the producers and markets in the Chapare. These efforts indicate that a variety of agroecologically suitable production options are available. Yet, factors such as credit and market availability seem to determine the acceptability of identified options. Thus, setting specific research priorities will continue to be difficult until marketing studies are completed for some of the identified alternatives (e.g., perennial tree crops). Lack of farmer representation in the project and lack of transition production systems[2] further constrain setting realistic research and extension priorities (22). Nevertheless, on-farm research and the production systems approach are valuable methorological tools arising from the Chapare project (box 4-B).

Considerable agricultural research has been conducted in Peru's Amazonia, covering agroecological conditions from the tropical highlands to the lowlands. Research programs and projects have addressed production problems in a variety of crops (e.g., rice, maize, grain-legumes, oilseeds, tobacco, coffee, cocoa, tropical fruits, and palms) as well as tropical soils management, tropical pastures, livestock production systems, and forestry. Research programs conducted in the 1980s increased yields and reduced production costs for rice, maize, potatoes, and beans, thus opening new technology options for the average producer in Peru. These programs yielded a substantial number of new varieties and cultivars adapted to diverse agroecological conditions and cropping techniques (79).

Several research centers located in the Amazonian and Orinoquian regions of Colombia have been active in developing high-yielding cultivars, and applying improved technology and management practices to support agricultural expansion. For example, high-yielding soybean varieties led to a 5-fold production area increase since 1985

[2] Transition systems are based on gradual reduction of coca cultivation and involve development of production schemes that integrate coca with legitimate crops. This approach offers security to risk-averse farmers during the lag time between planting alternative crops and receiving economic benefits.

Table 4-3-Current Production and Potential Increase of Some Alternative Crops **in the Chapare, Bolivia**

Crop	Current planted area (ha)	Mature crop production average (m f/ha)	Total production in the region (ret)	Value of product (FOB Chapare) (U.S.$)	Potential developed areas (ha)	Potential (5 yr) increase in total area (ha)	Value of increased production (U.S.$) (1991 prices)
Achiote	135	1.00	20.0	20,000	23,200	1,000	1,000,000
Bananas-Total	14,000	13.00	2,000.0	160,000	28,000	1,000	
Export	2,000					500	727,000
National	12,000		174,000.0	3,300,000	500	142,000	
Industry			40,000.0				
Citrus	20,000	40.00	800,000.0	12,000,000	27,000	1,000	600,000
Coffee	74	0.80	59.2	17,500	6,750	200	47,000
Ginger .,	8	13.00	106.0	42,000	2,000	50	264,000
Passion Fruit					5,620		
Export	21	10.00	15.0	4,000	300	810,000	
National			75.0	2,100		100	270,000
Industry			120.0	32,500			
Pepper	18	0.80	4.0	4,000	5,070	100	80,000
Pineapple-Total	274	13.50	582.0		3,100	500	891,000
Export	150			128,000			
National			978.0	110,000		500	2,700,000
Industry/losses			1,082.0	146,000			
Tea	55	5.50	302.5	49,000	7,500	200	178,000
Turmeric	44	10.00	120.0	12,229	1,500	500	510,000
Yuca	5,000	19.00	95,000.0	4,400,000		1,000	873,000
Total	53,779			20,446,229	109,740	7,450	9,092,000

KEY: FOB = Freight on board/shipping point; mt = metric ton.

SOURCE: B. McD. Stevenson, "Post-Harvest Technologies to Improve Agricultural Profitability," contractor report prepared for the Office of Technology Assessment, March 1992.

Box 4-B—Examples of Successful Bolivian Research and Extension Efforts

The most dynamic agricultural region in Bolivia is the eastern plains, with 50 percent of national agricultural land. Only 20 percent of the population, concentrated mostly around Santa Cruz, occupy this region. This area is likely to provide the most immediate agricultural expansion in Bolivia, and some successes can already be cited. Soybean production, for example, has jumped from 67,000 hectares in 1965 to almost 150,000 hectares in 1966, accompanied by an average productivity increase of 20 percent. A new high-yielding cultivar (Totai) developed by Centro de Investigación Agrícola Tropical (CIAT) has been instrumental to this development. CIAT's work on other aspects of soybean production is outlined in a manual widely distributed among extension workers. CIAT soybean recommendations are based on field trials and open discussion of results.

Bolivia'spositive experience with soybean improvements can be attributed to several factors: Bolivia took full advantage of foreign technical development (in this case, genetic material and agronomic practices from Brazil) and the active involvement of private interests and collective action. CIAT used practical and effective methods of technical diffusion; and extensionists from private entities were trained and backed by CIAT to solve specific technical problems and to reach farmers with sound technical recommendations.

Another example of effective research and extension work in the Santa Cruz area is seen in CIAT and the Asociación de Productores de Oleaginosas y Trigo (ANAPO) 5-year plan for expanding wheat production to reduce wheat imports. This plan is supported by the recent removal of wheat import subsidies and P.L. 460 wheat sales. The Bolivian Government also will allocate revenues from P.L. 480 wheat imports to support research and extension and to finance seed production and marketing. An agreement between ANAPO and Santa Cruz's mill industry guarantees a minimum price for local wheat.

First year production under the plan (40,000 metric tons) was double the plan goal for that year, and saved the Bolivian economy an estimated $8 million in wheat imports. Bolivia's success with wheat, as with soybeans, can be attributed in part to technology and experience borrowed from neighboring countries. The specific wheat variety used (Cordilleraz) came from Paraguay; ANAPO traded soybean seed for wheat seed of this variety. For its part, CIAT has developed a comprehensive technology package for wheat production and is training extensionists.

Another success story is that of the Instituto Boliviano de Technología Agropecuario (IBTA) research in quinoa. New varieties with low saponin content have led to a wider consumption of this traditional product. IBTA also has produced barley varieties widely adopted in highland production areas. These and other ofIBTA's research successes are in the form of specific projects financed by external sources. As such, they have been isolated from IBTA's financial and institutional instability.

Finally, a long-term joint effort by the Bolivian Government, Cooperación Técnica Suiza (COTESU), and Centro Internacional de la Papa (CIP) to increase potato production throughout Bolivia with high-quality seed has been reaping results. Proyecto de Investigación de la Papa (PROIMPA) takes a multidisciplinary approach to this goal. Specific project areas include plant genetics, entomology, phytopathology, hematology, postharvest physiology, seed production technology, and socioeconomic. A complementary Dutch-supported project, Proyecto de Semilla de Papa (PROSEMPA), is aimed at strengthening local and regional capacities to produce commerical high-quality potato seed. PROSEMPA is basically a technology transfer/extension effort directly relevant to producers' problems and market realities.

SOURCE: A. Chavez, "Andean Agricultural Research and Extension Systems and Technology Transfer Activities: Potential Mechanisms to Enhance Crop Substitution Efforts in Bolivia, Colombia, and Peru," contractor report prepared for the Office of Technology Assessment, December 1991.

and yield increases. Other crops being examined for expansion include rice, oil palm, mace, sorghum, cassava, and tropical fruits. In addition, research on tropical pasture and soil management is performed at the Macagual Regional Research Center in the Amazonian region. Results from the Orinoquia could be transferred to other areas of the Colombian Amazon, although such an effort would require greater investment in extension activities (22).

Intensifying Agricultural Production

Diverse, multiple cropping[3] systems have a history in the Andean coca growing regions and thus provide a likely starting point for intensifying agricultural production (46). Sustainable systems that preserve the natural renewable resource base and provide long-term environmental and economic benefits to farmers are needed (box 4-C).

Box 4-C—Criteria for Measuring Agroecosystem Sustainability

- **Low dependence on external, purchased inputs.**
- **Use of locally available and renewable resources.**
- **Beneficial or minimal direct or indirect negative impacts.**
- **Adapted to or tolerant of local environmental conditions.**
- **Focus on long-term productivity.**
- **Conservative of biological and cultural diversity.**
- **Incorporate traditional knowledge, skills, and aspirations.**
- **Adequate production to provide for local consumption and exportable goods.**
- **Integrates components at all organizational levels (i.e., crop, farm, local, regional).**

SOURCE: S. Gliessman, "Diversification and Multiple Cropping as a Basis for Agricultural Alternatives in Coca Producing Regions," contractor report prepared for the Office of Technology Assessment, February 1992.

MULTIPLE CROPPING

Traditional multiple cropping systems make use of locally available resources and provide for local consumption needs while also contributing to regional or national markets. The key feature of multiple cropping systems is the intensification of production to include temporal and spatial dimensions (box 4-D). Production focuses on long-term sustainability of the system. The continued productivity of traditional multiple cropping systems provides the kind of social and ecological stability that modern monoculture systems have not achieved.

Multiple cropping can have a definite advantage over monoculture systems (46,40,57,128) (e.g., total crop yield can be greater than that achieved in monoculture systems). In some cases, the yield of one crop may be lower than under monoculture, but the yield of the companion crop is sufficiently greater to offset any loss. Land Equivalent Ratios-the amount of land needed in monoculture to produce a yield equal to that achieved through intercropping of two or more crops-developed for a number of common tropical crops indicate that greater production may be achieved through intercropping compared to monoculture (57,111) (figure 4-l). Of course, crop complementarily and proper crop mixtures must be determined to achieve such results.

Multiple cropping systems mimic the energy and nutrient cycling processes of natural ecosystems. Characteristics common to natural and multiple cropping systems include:

- Return of organic matter to the soils (enhancing nutrient cycling, improving fertility, and reducing needs for external inputs);

[3] *Multiple cropping, nuked cropping,* and *polyculture* are terms used to describe agricultural systems that incorporate spatial and temporal dimensions in production. For the purposes of this discussion, such systems will be referred to as multiple cropping.

[4] *Sustainable* refers to the ability of an agroecosystem to improve or maintain production over many generations despite long-term ecological constraints and disturbances or social and economic pressures (3).

Box 4-D-Classification of Types of Multiple-Cropping Systems

Multiple cropping is the intensification of cropping intimeand space dimensions generally defined by growing of two crops in the same field within the same year. This type of cropping maybe further defined as intercropping or sequential cropping.

Intercropping: Growing of two or more crops simultaneously in the same field. Crop intensification is in time and space dimensions. However, under this system, potential for competition and growth interference exists during all or part of the growth period. Thus, crop complementarily is a key concern in developing production systems. Varieties of intercropping include:

- ***Mixed intercropping*—growing** two or more crops simultaneously with no distinct row arrangement,
- ***Row intercropping*—growing** two or more crops simultaneously with one or more crops planted in rows,
- ***Strip intercropping*—planting** crops in strips wide enough to permit independent cultivation but close enough for them to interact **agronomically,** and
- ***Relay intercropping*—growing** crops simultaneously for some part of each others life cycle. Typically, the second crop is planted after the first has reached a certain growth stage but before the first crop is ready for harvest.

Sequential cropping: growing two or more crops in sequence on the same field each year. The succeeding crop is planted after the first crop has been harvested. There is only temporal intensification and no intercrop interference or interaction. Sequential cropping maybe further defined based on the number of crops incorporated in the crop year (e.g., double, triple, quadruple, and **ratoon** cropping).

SOURCE: S. Gliessman, "Diversification and Multiple Cropping as a Basis for Agricultural Alternatives in Coca Producing Regions," contractor report prepared for the Office of Technology Assessment, February 1992.

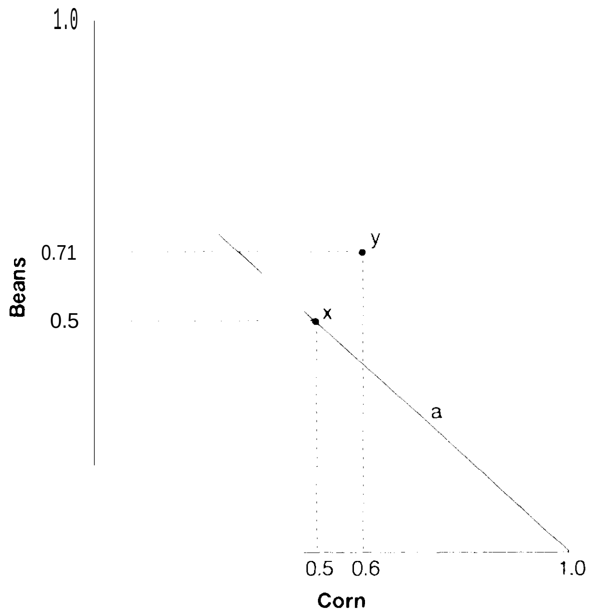
- Soil conditioning (e.g., improving soil moisture storage, increasing soil biota populations, soil stabilization);
- Plant diversity;
- Suitability to varied soil, topographic, and altitude conditions; and
- Efficient resource capture due to the varied rooting geometries, canopy patterns, and beneficial associations with other ecosystem components (e.g., nitrogen fining soil bacteria).

Under the moist tropical conditions of most coca production zones, farmers produce a variety of crops per year under a sequential cropping system. This requires timely harvests, appropriate cultivars, and proper sequencing to minimize potential negative interactions. It can be expanded to forma continuum from strict sequential cropping to relay intercropping for additional beneficial effects. Indeed, much of the agronomic research conducted in the Andean nations has focused on the potential for beneficial associations among early planted crops and later crops. These early crops improve microclimatic conditions so that growth of later, often more economically important, crop species is enhanced (122). Such advantage reaches its greatest point when mutualistic or symbiotic relationships occur that permit plants in mixtures to do better than when planted alone (45). The ideal mixture provides income and food for the family.

Largely, coca farmers are smallholders and produce a composite of subsistence crops and coca. Risk aversion is a kev feature of these production systems. There are-numerous socioeconomic advantages of multiple cropping systems compared with monoculture systems for the humid tropic regions, including:

- Reduced risk from market changes, pest infestation, and climatic variability;
- Greater energy cycling (reducing the need for costly external inputs);

Figure 4-l—Land Equivalent Ratios



In this example, one hectare of land is planted half in corn and half in beans. The expected yield based on monoculture projections falls on line **a** at point **x**. In many cases, however, the yield of each crop is greater than expected (point **y**). The observed production at point **y** shows that under monoculture 0.71 hectares and 0.6 hectares would be required for monoculture bean and corn production respectively. Therefore, the total amount of land needed to produce an equivalent amount under monoculture would be the sum of the two, or 1.31 hectares. The Land Equivalent Ratio, then, is 1.31 - translating to roughly a one-third increase in production under intercropping as compared with monoculture production.

SOURCE: Adapted from: D.C.L. Kass, "Polyculture Cropping Systems: Review and Analysis," *Cornell International Agriculture Bulletin* 32:1-69, 1978; B.C. Trenbath, "Biomass Productivity of Mixtures," *Advances in Agronomy* 26:177-210, 1974; C.A. Francis, *Multiple Cropping Systems* (New York, NY: McMillan, 1986).

- Harvest periods throughout the year (providing better annual distribution of income and farm labor needs/opportunities);
- Faster returns (earnings) from combining short-, medium- and long-term crops; and
- A diversity of products (reducing the need for purchased supplies such as fuelwood and construction materials).

Multiple cropping systems are more complex than monoculture systems, having greater agronomic and biological diversity and a greater need for hand labor. In coca zones where labor is expensive, therefore, these systems might be economically handicapped. Improved yields are highly dependent on appropriate system structure. A large body of traditional knowledge of multiple cropping systems remains in the Andean countries and could provide a research and extension resource for improving multiple cropping systems.

AGROFORESTRY

Incorporating trees in multiple cropping systems—agroforestry--is a traditional tropical and subtropical agricultural practice. The objective of most agroforestry systems is to generate diverse products, reduce external input requirements, and sustain resource productivity (44).

Agroforestry systems may be designed to produce trees with crops, trees with livestock, or trees with crops and livestock. The level of complexity increases along the continuum. Generally, little soil disturbance is involved once the agroforestry system is developed. The environmental benefits of agroforestry are well-identified and the principal limitations to widespread use are largely economic, social, and technological.

Home gardens have the greatest complexity but also offer the greatest product diversity. A widely used agroforestry system in tropical areas, home gardens are broadly defined as a piece of land with definite boundaries usually near a house, occupying an area generally between 0.5 and 2.0 hectares (2,21 ,78). They are an integrated system of humans, plants, animals, soils and water, with trees playing key roles in ecology and management. Home gardens tend to be rich in plant species, usually dominated by woody perennials, and generally have multistoried canopies (1,23). A mixture of annuals and perennials of different heights form layers of vegetation resembling a natural forest structure. The high diversity of species permits year-round harvesting of food, fuelwood, medicinal plants, spices, and ornarnental plants (24,47,48).

STEPHEN GLIESSMAN

Home gardens are a common feature of tropical agriculture. This diversified home garden agroforestry system in Costa Rica generates multiple products including banana, papaya, and pineapple.

Much of the coca production region is characterized by brush fallow and poor second-growth forest that could be used for agroforestry. The U.S. Agency for International Development (AID) sponsored research in the Chapare region suggests that many of the promising agricultural alternatives to coca are nontraditional tree crops, such as macadamia and peach palm and long-cycle perennials such as passion fruit and black pepper (4). Incorporating these economic crops into an agroforestry system could provide increased economic and environmental benefits for producers.

Agroforestry systems are being developed by *Instituto Nacional de Investigación Agraria y Agroindustrial* (INIAA) in Peru incorporating cassava or beans, fruit trees, and timber species *(Schizolobiurn amazonicum* or *Guazuma crinita). This* combination allows producers to use their low fertility soils unsuitable to production of other crops. Although the income generation capability of this system is low in the initial years, when the timber species becomes harvestable (6 to 8 years) it could generate as much as U.S. $1,500/ha with harvests being made every 3 years (122). Hand labor and investment requirements for this system are low. However, potential for pest infestations is likely to be higher in the mature timber monoculture and could create additional maintenance costs.

Potential also exists for interplanting timber species in coca fields to diversify production. While coca cultivation would benefit timber growth, it also would provide a source of income for the farmer until the trees are harvestable. Ultimately, the trees will shade out the coca and reduce production. Such a ''natural' eradication scheme initially may need to be coupled with other incentives (e.g., subsidies to maintain the forest until maturity) to encourage adoption.

Despite the apparent benefits of multiple cropping systems, little research has focused on optimizing plant densities. Incomplete understanding of the ecological processes of these systems complicates identifying ideal combinations and patterns. Applied research on crop combinations, patterns, and planting densities could be promoted under existing alternative cropping research, for example, through IBTA-Chapare. Demonstration activities could be undertaken to provide examples for local farmers and perhaps increase system adoption. In addition, research at each demonstration site could identify specific environmental differences among production zones and promote adaptive work to optimize production systems.

Improving Production Efficiency

Improving production efficiency, by reducing costs of required inputs or increasing output, can increase economic returns to producers. Production efficiency can be improved through use of proper fertilizer regimes, pest control systems, improved soil and water management practices, and improved cultivars. However, inadequate infrastructure, extension and technology transfer, and agricultural credit constrain use of improved practices.

Lack of infrastructure causes production inputs to be costly and difficult to obtain. Many cropping systems previously described focus *on* reducing needs for external inputs; nonetheless, some inputs are needed to sustain agricultural land use. The infrastructure problem is being addressed by a number of multilateral and bilateral agencies in the forms of road development, irrigation projects, and energy production systems. However, lag time between project initiation and realization of benefits is likely to be lengthy.

Extension of improved production practices (e.g., Integrated Pest Management, cropping system management) is hindered further by inadequately developed national agricultural systems and concerns over personal security. While extension occurs, it is small scale relative to the overall need (see chapter 5).

NUTRIENT MANAGEMENT

Addition of nutrients to a cropping system is an accepted axiom of agricultural production. Agricultural products, whether plant or animal, remove nutrients from the land on which they are produced. Even well-maintained organic farms that carefully collect and return crop residues and livestock wastes to the soil only replace part of the soil nutrients extracted. The other available nutrient sources internal to the agroecosystem (e.g., rock weathering, soil minerals, soil animals) are unlikely to make up this deficit. Fertilizer costs in most coca producing regions are high (U.S. $300 to 400/mt vs. U.S. $ 220/mt on the international market (122)), indicating a need for efficient fertilizer programs and use of alternative nutrient sources (e.g., green manure, nitrogen-fixing plants).

PEST CONTROL

Agricultural losses to pests significantly reduce production each year and costs for pest control place added burdens on producers. It is possible to optimize pest control and reduce pesticide needs using a variety of methods, including crop rotation, crop monitoring, pest-resistant cultivars, timing of planting and harvest, and biological controls.

Pest control may be initiated based on pest scouting-monitoring to determine a pest problem. Depending on the type of pest identified, the organization of the production system, and the extent of infestation, various control approaches may be used. Crop rotation and manipulation of planting and harvesting dates can break the life cycles of many pest species. Cultural controls such as tillage and water management can render the crop environment less favorable for pest populations.

Integrated Pest Management (IPM) blends the suite of pest control technologies into a single system designed to benefit (economically and environmentally) the user and society. IPM programs attempt to restructure an ecosystem to minimize the likelihood of pest damage. Programs are meant to be adaptive with an objective of improving program efficacy over time. The ultimate goal is to maintain pest populations at near-harmless levels.

SOIL AND WATER MANAGEMENT

Management of the soil and water environment for crop production requires understanding the interaction of these cropping-system components, and the suitability of the chosen crop(s) for the agroecosystem. Production of crops ill-suited to a given region may require more intensive external inputs, such as pesticides and fertilizers, to overcome the associated plant stress responses and to achieve acceptable yield levels (16).

Use of soil- and water-management techniques can adjust or modify the agroecosystem to enhance crop production and thus affect the requirements for external inputs. For example, soil-management practices designed to improve the friability and moisture-holding capacity of soils can facilitate crop root development. This in turn may improve the plants' nutrient extraction capability, thereby reducing the need for external nutrient inputs.

CROP MANAGEMENT

Crop management refers to the numerous decisions that most directly relate to the crop, including cropping pattern (e.g., rotation, intercropping) and crop or cultivar choice. Certain crop-management alternatives and techniques may complement or enhance nutrient and agrichemical management activities. Crop-management decisions may have direct impacts on agrichemical use and on how such compounds will behave and move through the agroecosystem. Crop choice alone has instant implications for the pesticide and fertilization regime a producer will use. Similarly, certain cropping patterns, such as legume-based crop rotations, may supply plant nutrients and break pest cycles for a subsequent crop and thus reduce agrichemical requirements.

Conclusion

Alternative crops must compete with the low-risk economic scenario associated with coca production. Although scattered economic data on potential alternative crops suggest that there are no legitimate economic equivalents to coca[5] (table 4-4), this could change if benefits of legitimate agricultural activities increased. Without improved production techniques, technical assistance, and other associated services, however, the chances are slim that substantial numbers of farmers will voluntarily adopt alternative systems. Despite some encouraging signs that coca profitability is decreasing, alternatives will still need to be economically attractive. Development of systems that allow incremental diversification of coca cropping with a goal of replacement may hold promise.

Constraints to crop diversification fall largely in the areas of support systems. While improved cultivars, cropping combinations, and production technology are available, extension of these to producers is hindered by inadequate extension and technology transfer systems (chapter 5). Primary constraints include:

- Input availability and costs (agricultural chemicals, machinery),
- Labor availability and costs,
- Credit availability and terms,
- Land tenure systems,
- Market availability (domestic and international), and
- Security risks.

Irrespective of the identified difficulties, legitimate agricultural production in the Andean nations could be enhanced. Some crops, production and processing technologies, and markets are available. Although new crops that might improve the economics of agricultural production have been identified, further research is needed to identify appropriate cultivars, production techniques, and market potential. Understanding that crop diversification is as important as interdiction has reached high political levels in the Andean nations and leaders have identified the need for concomitant efforts on these fronts.

FOREST RESOURCES[6]

Bolivia, Peru, and Colombia have substantial areas of remaining natural forests with potential for biodiversity conservation and forest management. These tropical wet forests and tropical pre-montane rainforests contain large numbers of tree species, epiphytic plants, lianas, and vertebrate and invertebrate animals (50). For example, the Palcazu Valley in east-central Peru contains at least 30 species of fish, primarily food fish (10); at least 50 mammalian species, at least 400 bird species, and numerous reptiles and amphibians (17); and between 5,000 and 10,000 vascular plant species. Almost one-half of the nearly 30 mammal species that could be of economic importance are rare or very rare and require protection to ensure their survival (33). Early

[5] While coca appears to be more profitable than suggested alternatives, this has not been proven. Classical benefit/cost analyses may not be an appropriate method for such economic analysis because of the illegal nature of the coca economy.

[6] This section was drawn largely from: D. McCaffrey, ''Biodiversity Conservation and Forest Management as Alternatives to Coca Production in Andean Countries, ' contractor report prepared for the Office of Technology Assessment August 1991.

Table 4-4-internal Rate of Return (net cash flow/costs) for Some Alternative Crops

Crop	Internal rate of return	Data area	Data year	Year at positive cash flow
Coca	165.4			2
Annatto (Achiote)	20.0	Pucallpa, Peru	January 1992	4
Araza	20.2	Pucallpa, Peru	November 1991	6
Banana (export)	53.8	Colombia		2
Black pepper	22.9	Pucallpa, Peru	January 1991	5
Macadamia	54.0	Colombia		5
Orange	29.0	Pucallpa, Peru	February 1992	5
Passion fruit	41.9	Peru	March 1992	4
Peach Palm	82.2	Ucalyi, Peru	January 1992	2
Pineapple	40.3	Pucallpa, Peru	January 1992	2
Rice	22.3	Tarapoto, Peru	March1992	1

SOURCES: H. Villachica, Lescano, C., Lazarte, J., Chumbe, V., "Estudio de oportunidades de inversión en desarrollo e industrialización de cultivos tropicales en Pucallpa," Perfil de proyecto para la planta de coloantes naturales y para la planta de conservas de palmito, Convenio FUNDEAGRO, Región Ucayali, Lima Peru, 1992.
Coca-H. Villachica, "Crop Diversification in Bolivia, Colombia, and Peru: Potential to Enhance Agricultural Production," contractor report prepared for the Office of Technology Assessment, April 1992.
Banana--J. Arbeiaez, "El Cultivo de Plátano en Zona Cafetera, Federación Nacional de Cafeteros," Bogota, Colombia, p. 40, 1991.
Macadamia-O. Rincon, "El cultivo de Macadamia, Federación Nacional da Cafeteros," Bogota, Colombia, p. 29, 1990.

estimates suggested that between 100 to 1,000 species could become extinct if this forest area was removed (39). Based on ecological similarities, it may be assumed that equivalent levels of biodiversity exist throughout the coca-producing regions in South America.

Deforestation occurs in all parts of each country (table 4-5) and in large part is correlated with coca production. Currently, deforestation affects large areas in the eastern Andean foothills and the Upper Amazonian lowlands of each country. Despite this, promoting protected areas and forest management in these zones could provide conservation benefits and alternative livelihoods for existing populations.

It has been suggested that many areas now supporting subsistence farming, including the production of coca for cocaine manufacture, might best be returned to long-term forestry development as the most ecologically sound land use. Considerable effort and state support would be needed to promote such a program although significant employment and economic benefits could arise from sustainable forest management approaches. However, the intensive subdivision of the land makes this a very difficult proposal to implement (105).

Protected Areas

Protected areas include conventional protected areas (e.g., national parks, forest reserves) and more recently biosphere and extractive reserves. However, some disagree as to how well extractive reserves function as mechanisms of forest/diversity conservation (19). Lands set aside for indigenous peoples also may serve as protected areas. Ownership and management commonly is public although some areas are privately owned. Use restrictions control the level of access and nature of extractive activities in protected areas.

Protected area management typically requires identification of suitable sites based on conservation criteria and formal establishment within the national system of protected areas. Although the size and extent vary among the protected area systems in the Andean countries (table 4-6), the necessary institutional framework exists.

Protected areas also provide indigenous peoples a method to gain or maintain access to culturally important wild resources. For example,

Table 4-5—Forest Areas and Deforestation Rates in Andean Countries, 1980s

Country	Forest area (sq km)	Deforestation rate (sq km/yr)	Deforestation rate annual percentage
Bolivia	668,000	870	0.2
Colombia	517,000	8,900	1.7
Peru	706,000	2,700	0.4

SOURCE: World Resources Institute, *World Resources 1990-1991: A Guide to the Global Environment* (Oxford: Oxford University Press, 1990), table 19.1 In: McCaffrey, 1991.

Table 4-6—Protected Areas in Andean Countries, 1985

Country	Number of protected areas	Total area protected (sq km)	Percent national territory protected
Bolivia	12	47,076	4.3
Colombia	30	39,588	3.5
Peru	11	24,076	1.9

SOURCE: World Resources Institute, International Institute for Environment and Development, *World Resources 1986: An Assessment of the Resource Base that Supports the Globa/ Economy* (Oxford: Oxford University Press, 1990), table 19.1 In: McCaffrey, 1991,

16 Yanesha Native Communities occupy 580 square kilometers of forest and agricultural land in the lower Palcazu Valley (1 14), The national park and protected forest provide for conservation, research, and tourism, and the communal reserve provides for traditional uses by the Yanesha people. Ultimately, greater economic benefits (in terms of tourism dollars) could arise from the maintenance of these wild areas, as is evidenced through expanding ecotourism markets worldwide (15).

However, national governments do not provide adequate legal backing, sufficient staffing, and financial support for protected areas (18). Thus, protected areas frequently cannot meet desired conservation goals and often exist as ‘‘paper parks’ ‘ that do not fulfill their mandate. The Isiboro-Secure National Park in Bolivia possesses many of the qualities that identify a highly appropriate protected area and also provides for the needs of the Yuracare and Mojenio native peoples. However, the park is located in an active area of coca cultivation. Its boundaries are breached increasingly by coca cultivators, loggers, and hunters (88,89), and enforcement is inadequate to control poaching.

Forest Management

Forest management describes the use of technical practices designed to increase the flow of benefits from forest resources. Management may be strictly for sustainable yield of forest products like timber and wildlife and may provide indirect benefits like erosion control over the long term. Benefits may be harvested or generated continuously or cyclically. Multiple-use management programs seek to provide numerous, often diverse, benefits from forests. Some spatial and temporal separation of benefits maybe associated with multiple-use systems since uses may not be compatible (e.g., forest preservation and lumber operations).

Forest management can be applied to primary, secondary, and heavily disturbed natural forest systems. Practices vary depending on the level of disturbance and the desired benefits from management. All of these forest types as well as some

Slash-and-burn forest clearing commonly is used to access agricultural lands, but land productivity tends to be short-lived. Evidence suggests that maintaining forests for sustainable timber operations and extractive reserves may offer longer term economic benefits.

small areas of planted forest are found in the coca-producing regions.

Forest management in the coca-producing regions could offer significant environmental and economic benefits to local populations. Forest systems offer a mechanism to reduce soil erosion, increase soil fertility, sustain biological diversity, and manage water resources. An economic dimension can be added to the environmental benefits by careful and systematic selection of forest trees for economic benefits. Selective removal of undesired species and regeneration of desired species can maintain the basic character of the forest while increasing the flow of economic benefits. Similar principles could be applied to other economically important forest plants and wildlife.

Potential also exists for managing traditional subsistence swidden-fallow agriculture to increase the abundance of economically important plants. Typically, the fallow period of agricultural lands involves allowing regrowth of naturally occurring plants for later removal once soil productivity has been enhanced. Selective removal of plants as opposed to slash-and-burn practices can contribute to maintaining a seed source for desired species. Ultimately the composition of plants can be shifted toward more economic forest species (117).

Technical Considerations in Forest Management

Forest characteristics (e.g., species composition, age), site environmental features (e.g., slope, climate), and external factors (e.g., roads, processing facilities) are important considerations in developing forest management and extraction plans (53). There is protocol to manage tropical timber forests based on natural regeneration of harvested tracts (108,1 10) (box 4-E). Selective cutting, enrichment planting, or plantation establishment regimes may be used to manage and exploit secondary growth and disturbed forests (75).

Incorporating the participation of the local population and providing them with tangible economic benefits can improve the success of forest management efforts (90). Reconciliation of local interests with national policies and identification and quantification of environmental benefits and potential beneficiaries are also necessary for forest management to be effective (80). Ideally, forest management pays for itself by generating high-value products in the short term. Alternatively, external economic incentives may be required to support such management (73).

Pilot forest management activities in undisturbed and secondary growth forests are ongoing in the American tropics. Largely these activities have concentrated on timber production, although some effort has been placed on extractive reserves (90). Funding for these activities has come from private and public sources. The key lesson from these pilot activities is the lack of a single formula for successful forest management in wet tropical environments. Plan development requires careful examination and incorporation of environmental, sociocultural, infrastructural, and political features of a site.

Constraints to Forest Management

Opportunities to manage forests sustainably are constrained by a variety of factors, including:

- High demands placed on forest areas for land and forest products (e.g., conversion of forestland for agricultural purposes and exploitation of existing forest resources),
- Potential for long lag-time between plan implementation and realization of benefits for production systems in disturbed forests,
- Low value placed on forests and the view of forests as an obstacle to development (92), and
- Conventional economic analyses that ignore the value of future forest (76)

Forestry institutions have not grown to meet the additional challenges arising from increasing global concern over tropical deforestation (129). Several features of tropical forests complicate management efforts, including forest complexity, distance from urban centers, and widely varied values placed on forests by various sectors of society (90). The inherent difficulties with forest management are heightened in coca-producing regions that also must cope with economic distortions and environmental difficulties associated with coca production and processing practices (32).

Conclusion

A number of forest management approaches are applicable to the Andean countries. Local commitment and participation are key elements of all of these approaches. Efforts range from largely communal to commercial efforts, yet are based on a fundamental goal of enhancing forest production (table 4-7).

Some private organizations are promoting sustainable logging through negotiations directly with forest communities. This approach allows for gradual exploitation and gives local inhabitants incentive to protect forest to maximize economic benefits over the long term. Selective cutting techniques are used to remove high quality wood for high value markets. Resource sustainability and social equity are criteria for acceptability of potential agreements. Development of such sustainable harvest methods may provide an opportunity to maintain the tropical hardwood market in the face of increasing con-

Box 4-E—Sustainable Forest Exploitation: Case Example in the Palcazu Valley of Peru

Sustainable exploitation of forest resources in tropical areas commonly is viewed as having little potential because of the complexity of managing diverse, old-growth stands. In fact, estimates suggest that less than 1 percent of tropical forests currently are being managed sustainably. However, an innovative forest production system in operation in the Palcazu Valley of Peru is demonstrating that sustainable forest exploitation in tropical humid forests may be possible. The project emerged from an AID-sponsored subproject (the Palcazu Valley Development Project—PVDP) of Peru's Pichis-Palcazu Special Project (Proyecto Especial Pichis-Palcazu—PEPP). PEPP was promulgated by road development (Carretera Marginal de la Selva) along the base of the Peruvian Andes in the early 1980s and was intended to promote agricultural colonization in the region. The AID subproject was to maintain a part of the highway leading to the Palcazu Valley and provide rural development assistance.

The environmental assessment conducted by AID for the PVDP, however, indicated the agricultural potential for the valley was low and the region was environmentally unsuitable for a large-scale colonization scheme. Recommendations for low-impact development were made in the plans for AID's *Central Selva Natural Resources Management Project*, including a widespread production system for primary forest areas. The Tropical Science Center of Costa Rica developed an integrated forest production system based on interspersed, narrow strip clear-cuts in high, primary forest; a 40-year rotation; family or exchanged labor; complete use of all wood in the cut area; and animal traction for removal of products to roadside landings. Trees would not be planted in the clear-cut strips; natural regeneration from bordering high forest trees and stump sprouting would serve to maintain the forest and its species diversity. Production tracts would border primary or secondary roads to facilitate the transport of forest products to nearby processing plants and only processed products would be marketed.

However, PEPP focus remained on agricultural development in the region and land was titled to resident cattlemen for livestock production. The only remaining forested land had been titled to 12 communities of native, forest-dwelling Amuesha (Yanesha) Indians, several of which showed interest in the forestry proposal. Thus, the original forest management scheme was redesigned to fit the Amuesha Although scaled-down in size and funding, the development of the Yanesha Forestry Cooperative emerged from these efforts in 1985. The techniques envisioned for the larger project (e.g., labor intensive, animal traction, small-sized harvest equipment) were adapted for the Amuesha, including vertical integration, with the forest operators collectively owning the production, processing, and marketing operations.

Despite difficulties encountered by the Cooperative (e.g., an uncompleted processing plant, inadequate transport and road maintenance machinery, lack of working capital, and the threat of violence from insurgents and narcotics traffickers), it has managed to move ahead slowly. Today, the Cooperative product mix includes finished lumber, treated poles and posts, charcoal, and manufactured products. Although some difficulties have arisen in securing national markets for certain products, this may be a result of the existing economic situation in Peru. Nevertheless, shipments have been made to U.S. and European buyers at premium prices and sawn timber has effectively entered local markets. Evidence to date suggests that the Yanesha Forestry Cooperative is a sustainable forest production system.

SOURCES: J.A. Tosi, Jr., "Integrated Sustained Yield Management of Primary Tropical Wet Forest: A Pilot Project In the Peruvian Amazon," Tropical Science Center, Costa Rica, 1991, In: McCaffrey, 1991. M.A. Perl, MJ. Kiernan, D. McCaffrey, RJ. Buschbacher, and GJ. Batmanian, "Views for the Forest: Natural Forest Management Initiatives in Latin America," World Wildlife Fund, Washington, DC, 1991, In: McCaffrey, 1991.

sumer boycotts of tropical wood products for environmental concerns (133).

In addition to sustainable logging opportunities, economic benefits are becoming apparent from extractive reserves. For example, some estimates suggest that while converting forests to pastureland can produce about 220 pounds of meat per acre each year, leaving them standing could produce 2,750 pounds of food. Further, the value of the forest products (nuts, fruits, other) can reach twice the one-time logging revenue. Similarly, review of non-timber forest product value on two sites in Belize suggest that rainforest use as extractive reserves seems economically justifiable based on current market data and currency values (54). Recently, Colombia and Brazil ceded control of certain forests to native Indian populations for extractive reserves. Expanding on this trend will require developing local economies with an interest in conserving and maintaining the forests and demonstration that these activities can be economically attractive. Some current activities that might assist in highlighting the value of forests include efforts in Costa Rica, where forest samples are being collected and investigated for potential commercial value (104). If such ''prospecting' assures economic benefits for native communities, it could be incentive for conservation and maintenance of existing forests.

Interest is increasing in forest-related activities (e.g., extractive reserves, logging, nature tourism) in the Andean region. Research in the Chapare region suggests that many of the promising agricultural alternatives to coca are nontraditional tree crops, such as macadamia and peach palm and long-cycle perennials such as passion fruit and black pepper (4). In fact, the Chapare is ideally suited for a land use system based largely on forestry and to a much smaller extent on agriculture (109).

The importance of incorporating forest resource opportunities in substitution programs is clear. For example, according to several estimates, between 66 and 80 percent of coca producers in the Alto Huallaga were settled on

Table 4-7—Forest Management Approaches To Promote Sustainable Resource Exploitation

Project	Type	Location	Activity	Goal
Yanesha Cooperative	Cooperative	Palcazu Valley, Peru	Harvest of undisturbed natural forest using strip clearcutting.	Produce lumber, chemically treated poles and posts, charcoal, and firewood.
Portico	Commercial	Costa Rica	Harvest of single tree species from swamp forests.	Produce high-quality doors for international market.
Boscosa	Public/ private	Costa Rica	Reclamation of cut-over and secondary growth forests, management plans for sustainable use.	
Plan Piloto	Public/ private	Quintana Roo, Mexico	Rehabilitation of degraded forest, increase numbers of economic species through regulated harvest, natural regeneration, and enrichment plantings.	Harvest of economic tree species.
Extractive Reserves	Community	Brazil	Formalizing lands as extractive reserves through petition to national government.	Harvest of forest reserves (e.g., rubber, brazil nuts).
ANAI	Public private	Costa Rica	Works with small farmers to protect and manage local forest.	Integrated land use.

SOURCE: D. McCaffrey, "Biodiversity Conservation and Forest Management as Alternatives to Coca Production in Andean Countries," contractor report prepared for the Office of Technology Assessment, August 1991.

steep slopes when the *Proyecto Especial Alto Huallaga* (PEAH) was developed (11,34). Despite this knowledge, the project excluded land in steeply sloping areas-areas classified as suitable only for forestry or protected forest—and focused on areas suitable for agriculture or livestock production. Since the project addressed only the flat areas, the impact on coca producers was limited from the outset. Likewise, a development factor that should have been of major importance, a forestry component, was not even considered. This is a serious shortcoming given circumstances where lands classified as suitable for forestry use constitute a considerable part of the region (12). However, forestry and agroforestry, although promising, should be viewed as components of an overall package of land use practices that could provide stable incomes and improved environmental conditions for populations in the coca-producing regions.

WILDLIFE AND WILDLAND RESOURCES

Wildlife and wildland resources could provide an opportunity to expand renewable resource based development. Andean ecosystems support a broad variety of wildlife species that are, or might be, managed to offer alternative livelihoods for local populations. Potential wildlife markets include hides and fibers, pet, meat, and other animal products (e.g., bone). Techniques exist for managing a variety of amphibians, reptiles, fishes, birds, and mammals to provide these commodities.

Nature-based tourism depends on maintaining certain valued ecosystems to attract foreign exchange. Considerable efforts are being made to incorporate local communities in nature tourism development (e.g., Monte Verde) (7). Wildlife development, and particularly tourism, is likely to be curtailed by social, political, and economic pressures in target areas.

Development of wildlife resources for the national and international markets in wildlife and wildlife products may provide more immediate returns than tourism and may also provide abase for developing tourism industries. Ranching, farming, and collection of wildlife are dependent on maintenance of wild populations and critical habitats. Although farming and ranching may require greater capital investment than hunting, they also offer greater security in terms of supply consistency. Market demand for neotropical wildlife and wildlife products has been increasing steadily and exhibits sufficient profit margins to entice international investors (13,27).

South American wildlife products remain important traditional protein and fiber sources and have been exported for nearly 400 years (70,72). International conservation organizations have focused on sustainable development of wildlife resources, and international wildlife conservation treaties (e.g., CITES, Migratory Bird Treaty) have led to some control over the exploitation and international marketing of wildlife products. Despite these actions, considerable amounts of illegal hides flow from the region.

Wildlife-centered economic development has become more acceptable and research efforts are being undertaken to determine sustainable yields and appropriate husbandry practices. Techniques for raising certain wildlife species with little capital investment have been developed and are easily incorporated in rural communities. For example, experimental programs for ranching of green iguanas have spread from Panama to other neotropical countries (6,127). Licensing and protection policies are being implemented in the region that are making farming and ranching of wildlife more profitable than taking from the wild (97).

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[7] This section was drawn largely from: R.E. Ashton, Jr., "Potential Use of Neotropical Wildlife in Sustainable Development," contractor report prepared for the Office of Technology Assessment, December 1991.

Wildlife Farming and Ranching

Farming and ranching of reptiles and amphibians have been successful in several countries, including Bolivia. These operations provide hides, meat, and live animals for the international market. Animals tend to be superior to those collected from the wild since they are healthier, accustomed to captivity, and generally parasite and disease-free, A select review of live animal importers showed that 100 percent prefer farmed or ranched animals for these reasons (6),

Wildlife ranching and farming appear to be on the threshold of becoming a major industry in some areas. Only within the last year have South American iguanas and caiman reached the pet markets in the United States. Table 4-8 shows some species that retailers and researchers suggest as having the possibility for sales volumes sufficient to sustain an industry. Underlying research needs include information on sustainable yield levels, life history, and husbandry techniques.

Wildlife farming involves collecting enough stock from the wild to have a viable breeding base to sustain a captive population and produce a marketable commodity. Once the stock is collected, the captive population is sustained through breeding and recruitment from the wild is not required. Although farming may offer an opportunity to propagate rare species without harming wild populations (102), it may also result in little concern for sustaining the wild populations or their habitat since the economic value lies with the farmed populations. Farming may also be used to conceal wildlife harvests, as has been suggested to have occurred in Colombia under some of the recent captive propagation programs (35). Nevertheless, well-organized and managed wildlife farming programs can promote monitoring of exports and provide revenue for enforcement activities and local communities. Constraints to this approach include potentially high startup and operation costs to sustain the captive population.

Wildlife ranching is based on capturing wild stock and raising it to marketable size and quality and requires continuous replenishment from wild populations. While this form of wildlife production is preferred for species with large wild populations, it can affect the viability of those populations if management is inadequate. Indiscriminate collection of wildlife can lead to extinction (102). By necessity, wildlife ranching depends on the maintenance of wild populations and their habitats and thus may yield conservation benefits. Revenues generated through taxes on ranching systems could support enforcement and protection of the resource.

Local communities that may not be able to finance a full-scale ranching system may still participate and receive economic benefits through collection of stock for ranching activities. Cultures that retain strong hunting and gathering systems may then supplement their incomes through supplying ranching needs.

Sustainable harvest from wild populations requires understanding population dynamics. Although such information generally is lacking for many exploitable neotropical wildlife, there are options for developing sustainable harvest programs *in situ*. Harvest levels can be based on empirical evidence during the period that population dynamics data are collected (13) (box 4-F).

EXOTIC SPECIES

The introduction of exotic species for farming or ranching activities is controversial. Concerns center largely on the potential for escape and ensuing displacement of native species and ecosystem disruption, disease transmission to wild populations, and economic consequences resulting from predation of exotic species on native biological resources.

If introduced species are excellent competitors or predators, native species maybe displaced and ecosystems disrupted. Displacement may take the form of population decline or range limitations. In either case, if the native species is desirable, or economically important, the adverse impact is

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Table 4-8—A Partial List of South American Wildlife Species With Potential for Sustainable Development

Species	Current status	Potential status	Market
Invertebrates			
Butterflies	G,F	F,R	H
Beetles	G	G,R	H
Spiders	G	G,F	P
Tropical fish	F,G	G,F,R	P
Amphibians			
Treefrogs	G	G,R	P
Dendrobatids	G	R	P
Bufonids	G	G,R	
Salamanders	G	G	P
Crocodilians			
Crocodylus intermedius	G	R	H
Crocodylus acutus	G	R	H
Crocodylus moreleti	G,R	R	H
Caiman crocodilus	G,R	G,R	H
Caiman latirostris	G,R	G,R	H
Melanosuchus niger	G,R	R	H
Paleochuchus palpebrosus	G	G,R	P
Paleochuchus trigonatus	G	G,R	P
Turtles			
Geochelone denticulata	G	F,R	P
Geochelone carbonaria	G	F,R	P
Aquatic turtles	G	R	P
Lizards			
Enyalioides laticeps	G	F,R	P
iguana	G,F,R	F,R	H,P
Ctenosaura pectinata	G	F,R	H,P
Basiliscus sp.	G	F,R	P
Tubinambis sp.	G,R	F,R	H,P
Snakes			
Boa constrictor	G	F,R	H,P
Corallus sp.	G	F,R	P
Epicrates sp.	G	F,R	P
Eunectes sp.	G	F,R	H,P
Drymarchon corias	G	F,R	P
Lampropeltis sp..	G	F,R	P
Spilotes pullatus	G	F,R	P
Lachesis muta	G	G	P
Bothrops sp.	G	F,R	H,P
Crotalus durissus	G	FIR	H,P
Birds			
Amazona sp.	G,R	R,F	P
Ara sp.	G,R	R,F	H,P
Other Psittacines	G,R	G,R,F	P
Mammas			
Tayassu pecari	G	R	H
Felis pardalis.	G	F	H,P
Panthera onca.	G	F	H,P
Lutra iongicaudis	G	F	H,P
Hydrocherus hydrocherus	G,R	R	H,P
Agouti paca	G,R	F	HIP
Vicugna vicugna	G,R	R	H

KEY: G = Hunted or collected.
R = Ranched or potential for ranching.
F = Farmed or potential for farming.
H = Animal products industry (e.g., hide, meat, feathers, bone).
P = Live animal trade.

SOURCE: R. E. Ashton, *Handbook on Central American Tourism and Wildlands Protection,* Paseo Pantera Ecotourism Project, Wildlife Conservation International, 1991, In: Ashton, 1991.

quickly apparent. In cases where the species is less obvious or desirable, the impact also maybe serious since the ecological balance will have been disrupted. Similarly, when introduced species prey on economic biological resources (e.g., crops, trees, fish), economic disruptions occur in the form of reduced yields, and increasing costs of control measures and management effort.

Nevertheless, species introductions are underway for potential economic gain. Nile crocodiles have been introduced on an Amazonian crocodile farm because of their higher quality hide compared with the native species. Accidental release of this prolific and potentially dangerous species into the Amazon basin could have serious consequences (97).

Asian and African big game have been introduced into some private game hunting ranches in savanna areas in Central and South America. Cattle associations in affected areas have re-

Box 4-F–Information Needs for Developing Sustainable Harvest Practices

- Population size and range.
- Habitat requirements.
- Resilience to human disturbance.
- Mortality and productivity rates.
- Key factors regulating populations and their tendency to increase or decrease.
- Effects of environmental variation (e.g., effects of climatic cycles) on productivity.

SOURCE: S.T. Beissinger and E.H. Bucher, "Can Parrots Be Conserved Through Sustainable l-harvesting? Bioscience 42(3):164-172, March 1992.

sponded with demands for strict control of these imports due to the potential for transmission of ungulate diseases to their stock.

INFORMATION NEEDS TO SUPPORT WILDLIFE PRODUCTION

Despite available technologies for wildlife production, species specific information is needed to support a viable wildlife production industry, Some of this type of research currently is underway for caiman and birds in South America. Biological studies are needed that characterize the extent of the resource and identify likely impacts of increased wildlife production and marketing.

Member countries of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) are required to provide a management plan based on recent surveys and studies on listed[8] species population dynamics and other key aspects affecting their viability. If it is determined that the species can be harvested, limits on the take are set to provide for the population to sustain or increase its numbers.

Allowable take limits must be based on solid scientific information regarding population size, dynamics, reproductive behavior, and current status. Species' feasibility for captive propagation is determined by behavioral, reproductive, and husbandry needs as well as economic value. Most species are not suitable for captive propagation (106) and comprehensive planning is necessary to avoid failure. For example, the United Nations, Man and the Biosphere and the United Nations Education, Science, and Cultural Organization 1970s project with tortoises failed to account for the time required to raise tortoises to market size for food. A component directed to the demand for hatchling tortoises in the pet trade might have been more appropriate.

Protection and Enforcement

Enforcement of wildlife protection and management regulations is a primary requirement for developing a sustainable wildlife exploitation program. Game laws typically have been difficult to enforce, and regulations have not been well supported since wildlife is considered part of the public domain (102). Most efforts at protection have been directed by international laws and treaties such as CITES. However, funding for much needed enforcement and education programs typically has been low.

Political will and increased revenues will be necessary to support sustainable development of wildlife resources. Economic pressures from conservation groups and the international market could provide incentive for producing nations to adopt or enforce protection programs. Revenue from legitimate business could help in providing the capital necessary for implementing these programs. The American alligator harvesting program and the International Union for the Conservation of Nature and Natural Resources (IUCN) Crocodile Specialist Group are examples of programs to promote protection, enforcement, and licensing and to facilitate marketing wildlife products.

8 *Listed* refers to the identification of a species as rare or protected under CITES.

Economics of Wildlife Opportunities

Economic concerns include startup costs, technology costs, logistics, cost/benefit ratio, and marketing (127). Although there are no data showing that sustainable development of wildlife resources could protect natural ecosystems or become the dominant method for economic development for small rural communities, indications are that well-managed sustainable wildlife industry development can be economically attractive. For example the demand for natural leathers has remained stable and has prompted some to investigate producing leathers from nontraditional sources such as frogs and toads (97). Prices for hides or animal fibers (e.g., vicuna wool) vary and high-quality products may bring significant earnings. For example, high-quality crocodilian hides may bring as much as U.S. $100 for an average caiman or crocodile.

The exotic animal pet trade has grown, mainly over the last decade. Tropical fish exports from several neotropic locations comprise a flourishing multimillion dollar business. Conditions that have led to the popularity increase of exotic pets include:

- Expanding awareness of rainforest biodiversity and intrigue with associated wildlife,
- Affluent populations in urban areas that view exotic pets as status symbols and as being easier to care for (27,51,97),
- Increasing accessibility and availability of exotic pets, and
- Increasing availability of captive care and maintenance techniques and trained exotic pet care experts.

Nearly all species of birds common to the pet trade are being raised in captivity, perhaps as much as 75 to 90 percent of the demand. Farmed or ranched birds could pose an alternative to captive raised animals if accompanied by attractive prices. Costs of transporting live birds and the quarantine requirements may pose major constraints to entrance into this market (6). In addition, competition from illegal imports may hurt the exotic bird market. For example, it has been estimated that nearly 150,000 birds from various countries were imported illegally each year through Mexico, totaling roughly U.S. $1 million in receipts for bird trade (107). As Mexico has become a member of CITES, this situation is expected to change. Considerable research would be required to develop systems appropriate to the raising of mammals for the exotic pet trade. High investment costs and the extensive care requirements are key considerations.

Few areas within Bolivia, Peru, or Colombia have adequate infrastructure to enter the live animal export market. In addition, the current market structure is weighted toward enriching the middleman rather than the supplier. Prices paid to villagers are about 10 percent of the wholesale price. For example, a boa constrictor that might fetch U.S. $250 results in an earning of U.S. $0.50 to $5.00 for the individual capturing the boa. Clearly, market access must be improved to increase economic benefits to the supplier.

Significant concern exists over the importation of disease with live animal trade. Despite mandatory health certificates, quarantine, and other importation restrictions under the Animal Quarantine Regulations administered by the U.S. Department of Agriculture (USDA), illegal imports have spread some diseases.

Quarantine and certification of health requirements will need review if the spectrum of imported wildlife increases. As the agency responsible for quarantine and health certification of imported birds and mammals, USDA must be adequately equipped to handle these tasks at ports of entry. Even today, some importers indicate that the current status of bird and mammal quarantine and staff training for these duties is inadequate and responsible for some wildlife losses.

Regulations regarding importation of wildlife to the United States may need to be reviewed as wildlife production becomes more controlled. Regulations established to curtail overexploitation or illegal takings of wildlife will be inappropriate for farmed or ranched species. For example, under the Public Health Service Act only 4 hatchling to 4-inch carapace turtles or tortoises may enter the United States in a single shipment and they cannot be sold except for scientific or educational use. Clearly, this regulation would pose a considerable obstacle for imports of captive raised turtles or tortoises.

Wildlife- and Wildland-Based Tourism

Wildlife-based tourism has grown at least 20 percent annually since 1980 (58,99), and has been described as a reasonable approach for sustainable wildland development. Tourism offers an opportunity to earn foreign exchange and provide employment for local communities, Where tourism is developed properly, it has a greater potential for generating local income than most traditional farming or ranching activities (68).

Nature-based tourism could provide economic opportunities for the Andean countries. However, it should be noted that poorly developed tourism industries all too commonly degrade natural resources and ultimately may reduce development options. There are examples of well-planned, appropriately designed nature tourism attractions that could serve as models for similar development in the Andean countries. Ecotourism is gaining interest globally and expertise in developing these resources is expanding.

Game tourism has not reached the levels of big game hunting in Africa and Southeast Asia, although jaguar, tapir, peccary, white-tailed deer, and birds have been hunted in South America. Fishing in the Amazon has been popular for at least 20 years and has focused on such exotic species as peacock bass and giant catfish. Some game tourism is seasonaI in nature due to the migratory behavior of target species (e.g., ducks) and provides only short-term employment for local populations. Sustainable management of game resources will require development and enforcement of optimum harvest limits.

While studies have been conducted on the contributions of nature-based tourism to local cultures, they lack data on the level of economic contribution and volume. In fact, data on nature-based tourism's actual importance to local and national economies are lacking. There are no standard data collection methods by tourism officials or international organizations and researchers' poor knowledge of nature tourism (58,99) has led to ineffective study methods and erroneous conclusions.

Appropriate planning and management of wildland tourism areas must incorporate the needs of the local communities, fair user fees, and equitable distribution and use of revenue to maintain the attractions that sustain the industry. Where nature tourism has been developed, primary criticisms relate to failing to fulfill these needs. Tourism developed around indigenous cultures and wild areas may also offer an opportunity to preserve traditional cultures, skills, and knowledge. Also important is the investment of tourism revenue into the local society in terms of improving quality of life by providing employment, training, and education. Such revenue has been shown to contribute significantly to economic growth (8) and increase support for parks by local communities (62).

Developing successful tourism programs that support local communities should include:

- Written working agreement with communities or local people outlining the use of lands, jobs, interactions with tourists, wildlife protection and associated compensation for undertaking such activities, training, and advancement potential;
- Agreement describing operators efforts to support the local community;
- Agreement to the privacy rights of tourists and local populations; and
- Agreement on marketing goods produced by the local community that assures fair compensation and precludes overharvest of local resources upon which the industry depends.

If nature tourism increases in importance in the Andean countries, mechanisms will be needed to protect wild resources supporting the industry. However, competing demands for resources can pose a constraint to development and implementation of such regulations. For example, the Isiboro-Secure National Park in Bolivia provides a highly diverse forest system that could be of interest to nature tourism, but encroachment on park lands by squatters producing coca has adversely affected its tourism potential.

Conclusion

International and domestic markets for wildlife, wildlife products, and nature tourism exist. Developing these resources could contribute to overall economic improvements in the Andean region. Farming and ranching of wildlife species and protecting and preserving of habitats are techniques that could promote development of these sectors,

Revenues from sustainable development and exploitation of wildlife resources can support conservation efforts critical to sustaining the industry. Governments must set appropriate user fees and allocate revenue for habitat protection, monitoring programs, research and education programs, and maintenance of necessary infrastructure. Models of successful efforts (e.g., crocodilian programs) could provide the basis for developing rational revenue allocation schemes.

AQUATIC RESOURCES[9]

Abundant freshwater aquatic systems (e.g., lakes, reservoirs, rivers, and streams) in the Andean nations provide opportunity for sustainable exploitation of endemic and introduced fishes, other vertebrates and invertebrates, and plants. However, little development effort has been placed on improving existing commercial and artisanal fisheries.

Comparisons of estimated productivity and actual harvest suggest that a higher level of sustainable exploitation of Andean aquatic resources is possible. Use of better management, production, and postharvest technologies could increase fishery production. Well-designed management systems that include size, season, and gear restrictions can influence aquatic community composition and sustain high-value fisheries and protect the resource base. Such systems, however, need to be suitable to the local community and local input in developing management plans should be an integral part of such activities.

Use of improved capture technologies can allow more precise exploitation of aquatic communities and greater benefit per fishing trip. Aquiculture technologies offer an opportunity to increase food production through intensive fish farming through stocking to maintain commercial fisheries. Perhaps, the key need for improving the potential contribution of aquatic resources to the Andean countries will be efforts to reduce postharvest losses of aquatic products by improving processing, handling, and storage methods. Infrastructure development could assist in marketing, reduce product cost, and potentially increase economic benefits.

In some regions, coca production and processing have adversely affected aquatic systems and reduced their potential productivity. Aquatic remediation technologies could be applied, although clear definition of the problem will be necessary before undertaking reclamation activities.

Existing Fisheries

Commercial and artisanal freshwater fisheries in the Andean countries have not been a focus of development activities. Some commercial fisheries have been developed around introduced high-value species. For example, rainbow trout and pejerry introduced into Bolivian and Peruvian

[9] This section was drawn largely from: R. Schroeder, "Fishery/Aquatic Resources in Bolivia, Colombia, and Peru: Production Systems and Potential as Alternative Livelihoods, " contractor report prepared for the Office of Technology Assessment, October 1991.

lakes supported a commercial trout fishery until severe overfishing caused a significant stock decline (36,1 19). Pejerry is now the most abundant fish in these lakes and supports a major fishery in Bolivia. Pejerry is also cultured in lagoons and lakes at Cuzco and Apurimac in Peru (31). In addition to lake fisheries, river basins support active fisheries, including the Magdalena, Pilcomayo, Amazon, and Orinoco Basins.

Other aquatic animals and plants may have some potential as food and fiber resources. Amphibians, birds, mollusks, and crustaceans are found in the Titicaca Basin (42,120,121). Economically valuable plants (e.g., bullrush, algae, *Elodea*, *Myriophyllum*, and *Potamogeton)* are found in lakes and streams and rivers. These plant materials can be used for human and livestock food, construction materials, crop fertilizers, paper production, and medicines (69). Estimates suggest that sustainable totora—Scirpus *tatora* or bullrush--production in Lake Titicaca could feed 265,000 head of livestock. Development of these resources will require strategies to protect against overharvest and to enhance their growth (e.g., cultivation through careful cutting can enhance bed productivity and density).

Aquatic vegetation also provides nursery habitat for economically important fish and invertebrates, feeding areas for birds, and shoreline protection (65). Littoral swamps may extract contaminants from terrestrial runoff. Thus, maintaining or enhancing these resources could provide conservation and economic benefits for local communities.

Fishing communities of the Andean region typically are small and dispersed, with fisheries being largely artisanal and labor intensive. Artisanal fisheries are characterized by low-technology, high effort with seasonal fluctuation, limited fishing range, and landing of small quantities at scattered sites. Fishermen typically are low income, have few opportunities for alternative employment, and wield little political influence (74). Fishing tends to be a part-time occupation due to the seasonal nature of fisheries and migratory behavior of many economic species; full-time fishermen must migrate along riverine systems to follow stock (124). Fishing trips typically are short (e.g., several hours), and most fishermen are also involved in crop or livestock agriculture. Rapid development of large-scale fisheries could result in resource overexploitation to the detriment of these artisanal fishermen (82). Lack of formal training opportunities in fishing skills also poses a constraint to expansion of fishery development (63).

Fishing craft, gear, and methods vary widely depending on target species, whether the fishery type is artisanal or commercial, and whether the exploited aquatic system is a river, stream, lake, or reservoir. Boats range from paddled dugout canoes to small powerboats. Some traditional fishing gear (e.g., reed rafts, nets of llama wool, traps, and spears) is being replaced by more modern technology.

Marketing typically is dependent on fish traders and some traders may even provide small loans to fishermen (74). Although some products now reach distant markets, difficulties remain for long-distance marketing (81,82). Existing production and market system features reduce the potential for increasing fisher-y value in domestic markets. In the Lake Titicaca Basin, for example, export of high-value fish is controlled by middlemen and import of frozen marine products has undercut the price of native fish, which make up the greatest part of poor fishermen's catch (9). Thus, annual earnings for fishermen providing for local markets averaged one-half that of export-oriented fishermen (i.e., U.S. $1,200 vs. $2,400) (82).

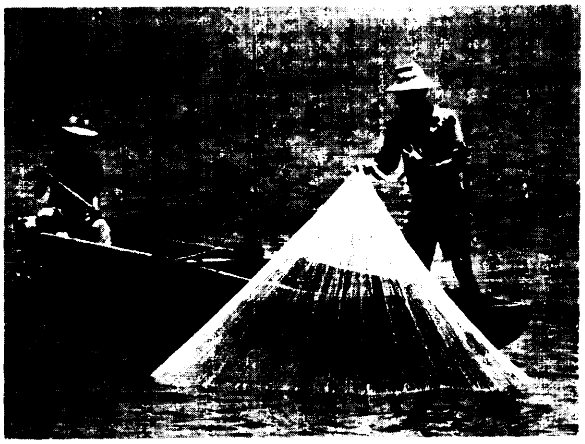
Management of Aquatic Resources

Fishery legislation typically has been difficult to enforce largely due to lack of public acceptability and the remote nature of many of the region's fisheries. A variety of regulatory measures may be needed to promote and sustain fishery development. These can include restrictions on total fishing effort, resource restoration, habitat enhancement, pollution controls, and selective removal of competitive species. Restriction on effort can include catch limits, licensing quotas, gear limitations, closed seasons and areas, and zoning guidelines for waterside development (124).

Ad hoc resource management is accomplished in some areas through community-controlled fishing territories-Territorial Use Rights Fishing (TURFS), whereby aquatic resources are defended from exploitation by outsiders. TURFS may extend from a few hundred meters to several kilometers from shore (64). Although the TURF system is not recognized legally, this informal management system may also function to sustain fisheries by preventing overexploitation. Conflicts between commercial and artisanal fishermen may be promulgated by fishery development since the latter primarily depend on higher yield/lower catch per unit effort fishes while the former depend on larger, high-value species. TURFS may function to defend harvest zones from commercial efforts.

Generally, fishery development focuses on high-value species and seeks to manage the entire system with respect to sustainable yield for these products. Without careful management, overfishing for high-value fish may result in community dominance by short-lived species that support greater sustainable populations. It may be possible to develop a balanced system for producing high- and low-value species, but management requirements are likely to be even greater. Elimination of competitors through a variety of methods (e.g., selective application of electrofishing or ichthyocides) can reduce pressure on desired fishery species. Understanding life history and basic biology of fishes can be used to develop harvest measures specific to certain life stages or species.

Effective management and compliance with fishery regulations also require an understanding of the importance of such measures at the community level. Active fisheries extension services can facilitate understanding of requirements, and community level organizations (e.g., TURFS) might offer opportunities to distribute information. Active local participation in the development of fishery management plans can also promote acceptability and compliance with these efforts. Management planning for the Titicaca Basin, for example, could incorporate the traditional TURF system with more formal management strategies and stress cooperation between the various stakeholders (63)



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Fishing gear vessels typically range from dugout canoes to small motor-powered boats, A dugout canoe allows these two Colombian fishermen to extend the area they can exploit with a castnet.

Increasing Fishery Production Potential

Methods to increase or improve fishery production at the commercial and artisanal levels, include use of improved harvest technologies, habitat improvement, and aquiculture. Aquatic systems are subject to numerous and competing demands from other activities (e.g., agriculture, urbanization, recreation). A primary consideration prior to fishery development or enhancement will be the additional surrounding activities that may have an impact on the aquatic system and strategies to integrate such competing needs with fishery development.

HARVEST TECHNOLOGIES

Improved fishing gear and methods could increase production in artisanal and commercial fisheries. Gear/method combinations vary depending on the target species, location, and water system; artisanal fishermen tend to employ a variety of nets, seining, and fishpots. These technologies are simple to implement and provide relatively inexpensive harvest methods. While previously constructed from local materials, nets and lines of more modern materials are now being used. However, boats are used infrequently, restricting the range of exploitation to nearshore environments. Dugout canoes that are handpaddled maybe used by some fishermen, but size and storage abilities also create harvest restrictions. Wider use of improved materials in traditional fishing gear and boats with greater capacity for proper catch storage could contribute to improved catch per unit effort in artisanal fisheries. Commercial fishermen also use a variety of nets for capture. Although some commercial efforts on Lake Titicaca focus on nearshore activities (i.e., beach seining for catfish), higher value species are captured from boats by pelagic gillnetting or trawling. Vessels commonly are equipped to store catch on ice to decrease postharvest losses.

HABITAT ENHANCEMENT

Actions that reduce habitat complexity threaten the diversity of fish populations. Variations in stream flow, siltation, and chemical inputs all may result in physical or chemical changes in aquatic ecology. Such effects are common in coca-producing and cocaine-processing areas where erosion from cultivation can contribute large amounts of sediment to nearby riverine systems and periodic dumping of processing chemicals into rivers and streams may change the water's pH balance temporarily.

Resource enhancement can be accomplished through physical (e.g., artificial reefs, fish ladders, current generation) and biological (e.g., stocking, selective exploitation) means. Artificial reefs have been used successfully in temperate lakes to increase abundance of economic fishes and might hold promise for high altitude lakes in the Andean region. Increasing exploitation pressure on competitive species can also improve productivity of desired species. Sufficient natural reproduction and recruitment to maintain a fishery require optimum conditions (e.g., water temperature, flow, clarity, substrate type, complexity) and, most often, regular stocking.

AQUACULTURE

Several organisms have culture potential for high-altitude tropical aquatic systems. Tilapia is the most popular freshwater fish cultured in tropical and subtropical regions. However, early efforts to promote small-pond culture of tilapia in certain regions of the Andes were unsuccessful. The program failed largely because plans lacked a strategy for the local population to produce fish food cheaply and easily (84). An integrated, farming systems approach could have addressed this need.

In Rwanda, small fishponds (0.8 ha) at altitudes of 1,300 to 2,500 meters have been found to be economically viable with production levels averaging 400 kg/ha/yr. Tilapia *(Oreochromis niloticus)* was found to be the most suitable species for this type of culture. Andean river shrimp have commercial aquiculture potential (120,121) and native freshwater prawns in mountain streams and lakes may have similar potential (67). Techniques for shrimp and prawn culture have been used successfully in tropical areas (115).

Aquiculture also can be used to complement capture fisheries by providing fingerlings for stocking. Characterization of the aquatic ecosystem is necessary, since artificial enhancements can alter interspecific competition (41,77). Increasing nutrient and organic content of natural systems and temperature elevations may cause undesirable shifts in natural aquatic communities (28). Algae also may be "stocked" to provide a supplemental food source for fish and be harvested as livestock feed, fertilizer, or for human consumption (135).

Floodplains may provide an area for expanded aquiculture activities by blocking small channels or depressions and constructing drain-in ponds and refuge traps. Annual production can average several hundred to a thousand kilograms of fish per hectare (124). Successful examples of transforming waterlogged soils in tropical floodplains into productive aquiculture/agriculture systems are evident in the Peoples Republic of China. Traditional dike-pond agriculture and aquiculture systems on the Pearl River Delta have been operating for at least 400 yearn. Fish, livestock, and agricultural crops are produced and material cycling contributes to reduced production costs (*box* 4-G).

HANDLING, STORAGE, AND TRANSPORT

Infrastructure development has lagged in providing the facilities necessary to promote fisheries in many areas. Indeed, key constraints to greater economic benefits from fishery production in Bolivia seem to center on inadequate infrastructure for processing, handling and storage, and lack of equipment to exploit the resource adequately. These difficulties translate into low prices for the fishermen and high prices for consumers. For example, in 1987 fresh fish prices were nearly three times greater in La Paz (market) than in Trinidad (production center) and only 25 percent of the price was retained by the fisherman (87). Development of roads, ice plants, marketing channels, and credit systems could support increased fishery development (126).

Conclusion

Aquatic resource systems of the Andean region harbor significant potential for enhanced production. The numerous lakes and river systems include a variety of harvestable species that could support artisanal and commercial fisheries under good management conditions and application of appropriate technology. Some systems clearly are underexploited and could provide significant increases in domestic food production.


DOUGLAS POOL, DEVELOPMENT ALTERNATIVES, INC.

Productivity estimates for Luke Titicaca, shared by Bolivia and Peru and covering 8,135 square kilometers range from 50,000 to 250,000 metric tons--far above actual yield estimates.

Despite the availability of resource assessment technologies, little information on aquatic resources has been gathered. Fishery research activities that demand the highest priority are stock assessment, aquiculture, fishery expansion, resource administration and management, handling and processing, and technical training to support enhanced fishery production. Assistance of an applied nature designed to address immediate problems could provide rapid results and the basis for demonstration and diffusion of new technologies and approaches to fishery production (14).

Quantitative and qualitative field assessments on the extent of aquatic resources are necessary to develop rational resource management plans. Information on species composition, recruitment, and life history help to establish sustainable harvest parameters. A variety of methods are available for gathering such information, some highly technical and others based on surveys at landing sites and local fish markets (125).

Box 4-G–Dike-Pond Aquiculture Systems

Blending of aquiculture and agriculture systems may hold promise for increasing productivity of floodplains or waterlogged soils. A notable example is the dike-pond system that has been used in the Pearl River Delta for at least 400 years. The system is composed of land and water subsystems linked through agriculture and livestock components. Byproducts from one subsystem become inputs for the other (29).

A diversity of fish are cultured in ponds (bottom, mid-level, and surface dwellers) and sugarcane, fruit trees, mulberry, forage crops, vegetables, and flowers are produced on the dikes. Poultry and livestock are raised near the ponds and silkworms are raised on the mulberry trees. The forage crops produced on the dikes are fed to livestock and fish. The livestock excrement is used to fertilize ponds and pond mud piled on dikes to fertilize crops.

Despite the antiquity of the Chinese system, scientific procedures for quantifying analyzing and experimenting with these farming systems are sparse. The International Center for Living Aquatic Resource Management (lClARM) is actively researching combined agriculture and aquiculture systems in India and Malawi. These efforts closely resemble those of the Chinese systems. As in agricultural crop substitution approaches, a key need identified through the ICLARM effort is mass farmer participation in the adaptive research and development process (66),

SOURCE: Office of Technology Assessment, 1993.

Models to predict the potential catch productivity of river fisheries can be based on characteristics such as channel length or drainage basin area; correlations with environmental parameters; or habitat variables (124,125). For example, standing stock may show a high correlation with stream width, width-to-depth ratio, extent of riparian vegetation, and dry-season stream flow (59). Primary productivity estimates-requiring examination of morphological, physical, chemical, and biological features of the resource-are also necessary in developing management plans (20).

Some work has been done on quantifying production potential of the riverine systems of the Altiplano (the large, high-altitude inland drainage plateau of Bolivia and Peru) (86) and the Magdalena River Basin of Colombia (52,1 18). The aquatic systems of the eastern and western cordillera of the Andes have yet unquantified production potential, although these resources could contribute to national protein production (132).

Development of sustainable resource management plans requires information on the current status of a wide variety of parameters, including:

- Resource production and potential,
- Fishing activity,
- Environmental health,
- Historical trends to identify critical variables, and
- Spatial and temporal variations in conditions.

Once this information is available, opportunities for developing sustainable exploitation strategies may improve. Such management strategies should contain at least the following components: resource enhancement/regeneration plans, financial support, regulation and enforcement measures, development of local organizational capacity and coordination, and training and extension.

STRATEGIES TO ENHANCE COCA SUBSTITUTION EFFORTS[10]

Development of the alternative economy being promoted in Andean countries to reduce dependence on cocaine *is* at a critical stage. Some promising alternative crops have been identified

10 The basis for this section was developed largely from: U.S. Congress, Office of Technology Assessment, Crop Substitution Workshop, September 30-October 1, 1991, Washington, DC.

and efforts continue to improve adoption and productivity of these systems. Largely the focus has been on agricultural crops as opposed to the broad range of renewable resource uses that might offer alternatives to coca production. Indeed, some coca production areas are identified as inappropriate for agriculture, yet suitable for forest management and production. Improving coca substitution programs in the Andean countries might be approached through:

- Diversifying agriculture systems,
- Intensifying agricultural production, and
- Expanding the range of resources exploited.

Some key principles unique to the Andean crop substitution effort create the framework within which improved substitution programs might be developed. First, the degree of economic and traditional dependence of Andean peoples on coca hinder acceptance of coca substitution programs linked to complete eradication of the crop. Coca is a traditional crop in Andean agriculture with a high degree of symbolism; further, it provides the largest share of export earnings for the Andean countries. Programs that approach crop substitution incrementally, therefore, may find greater acceptance than replacement strategies. Transition time from producing coca to producing alternative crops may be lengthy. Programs or projects must consider investment time for producers to make the transition to alternative livelihoods. Programs might focus on creating preconditions necessary to implement crop substitution programs, identifying how these programs fit with existing policies, and assisting in marketing and developing other support structures necessary for success of a substitution program.

Secondly, coca farmers tend to be smallholders, yet national agricultural policies (e.g., land-tenure, agricultural pricing and structure) seem to work against development of smallholder agriculture. Investment in improved agricultural production systems require access to affordable credit—a feature largely lacking for smallholders, particularly in coca production regions. Nevertheless, increasing profitability of national agricultural production is likely to depend on intensifying smallholder production systems. Progress toward the transition to alternative cropping systems in the coca-growing regions will depend on availability of improved technology and techniques, practices and cropping combinations, and a supportive policy environment at the local, regional, national, and international levels.

Finally, the extent of the cocaine economy in Bolivia, Peru, and Colombia highlights the size of the crop substitution task. If substitution programs focus on current coca-producing regions, environmental features will constrain the breadth of alternative crop choices. Coca grows on poor soils with low pH, high aluminum content, and low cation exchange--conditions few other crops will tolerate. Because of coca's value, carrying capacity of coca-producing regions exceeds that allowed through production of legal crops. Substitution efforts that seek to expand the range of resources exploited may be more successful than those that focus solely on a single resource alternative (i.e., regional economic development vs. alternative crops). Sustainable exploitation is key in such goals in order to maintain benefits in the long term. However, sustainable-use systems require development to support such resource use, and economic and sociocultural constraints must be addressed (e.g., market availability, practitioner skill). These features are important considerations and underscore the need for a flexible approach to developing alternative livelihoods for Andeans involved in coca/cocaine production.

Strategy: Diversify Agriculture Systems

Diversification of agricultural systems by incorporating high-value crops is the driving force behind current crop substitution efforts in the Andean countries. High-value agricultural exports offer potential to generate foreign exchange

Box 4-H–Estimated Economics of Intercropping Coffee with Annual, Semi-perennial Crops, and Shade Trees

The following table illustrates potential earnings from establishing a coffee, shade tree, semi-perennial, annual cropping system under good soil conditions. During the first 2 to 3 years of the system, annuals and semi-perennials are interplanted with the coffee to provide income (e.g., corn, cassava, bananas). Corn maybe planted in October/November followed by bananas in November/December. The coffee seedlings are planted in January/February, and the established corn crop provides shade to promote coffee seedling development. After the corn crop is harvested, legume tree seedlings are transplanted. At this point the banana development is sufficient to provide shade for coffee, and annual crops such as cassava may be interplanted for harvest in 8 to 10 months. Bananas produce 14 months after transplanting and can be harvested for 3 to 4 years. Banana tree density is reduced 30 to 40 percent annually until it reaches 10 percent of its initial planting density. By years 4 to 5 coffee is in full production and legume tree cover is sufficient to provide shade.

Year after planting	Crop	Yield (kg/ha)	Income (U.S.$/ha)
1	Corn	1,500	180
2	Banana	5,000	500
3	Banana	2,000	200
3	Coffee	275	210
4	Banana	1,500	150
4	Coffee	440	335
5	Banana	500	50
5	Coffee	660	503
6	Coffee	990	754
7	Coffee	1,175	880
8	Coffee	1,375	1,048

SOURCE: H. Villachica, "Crop Diversification in Bolivia, Colombia, and Peru: Potential to Enhance Agricultural Production," contractor report prepared for the Office of Technology Assessment, April 1992.

earnings and thereby increase the attractiveness of legitimate agriculture. For example, tropical fruits and nuts, coffee, and spices are impressive in terms of potential income per hectare produced because of their value in European, Asian, and U.S. markets. Although still lower returns than that generated by coca production, these commodities are viewed as having the greatest potential for competing with coca. Yet, at the same time, existing infrastructural constraints to moving these products to market can reduce their value at the producer level and create a disincentive to participate in substitution programs. Integrated systems of high-value and staple crops could provide a basis for agricultural diversification and increase agricultural profitability (box 4-H).

The Andean countries remain net food importers currently because cheap food imports are more cost effective than internal movement of foodstuff from production site to urban markets. Prices for traditional agricultural products are adversely affected by present agricultural structure and pricing policies. Nonetheless, crop diversification strategies could be approached in an incremental fashion with an initial focus on increasing production of traditional food products for local and regional markets and phasing in of high-value export commodities. Developing systems that integrate legitimate crops with coca offers an

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Irrigation networks can increase agricultural production, particularly in areas subject to seasonal rainfall. Here, farmers harvest green peppers on an irrigated cooperative farm.

option to reduce the perceived risk of transition to alternative systems for some coca producers. Coordinated effort could be placed on developing necessary infrastructure to support an agricultural export industry along with value-added processing to increase the economic benefits for local communities.

OPPORTUNITY: INCREASE IMPORT SUBSTITUTION

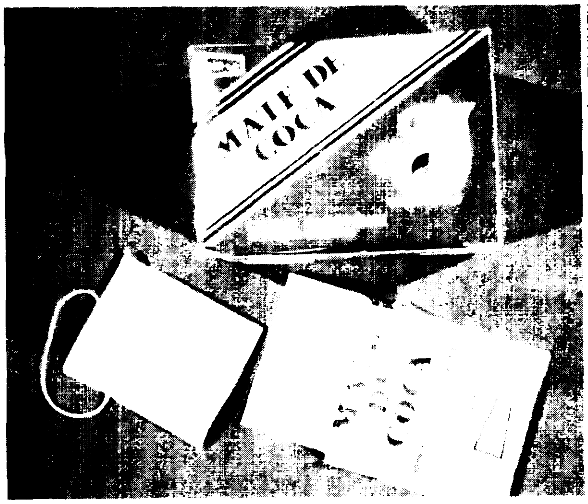
Diversion of land from legitimate agricultural production to coca production is suggested to have increased the Andean nations' dependence on foreign food imports. Production of typical Andean crops has declined; however, to what degree this may be attributed to expanding coca cultivation or to changes in food consumption patterns is unclear. Although increasing agricultural productivity of the Andean peasant economy through application of selective technological packages is now viewed more optimistically, such approaches may require redesign of certain rural strategies (e.g., Peru's Agrarian Reform) and significant infrastructure development and technical assistance (115).

While the economic conditions of the Andean countries imply that internal markets will not be high-priced, ability to market maybe increased if products and markets are in close proximity (e.g., a producer in the Chapare may stand a better chance of getting grain to La Paz than bananas to Chile). Price differentials, however, will constrain this approach and may result in a need for additional economic incentives associated with substitution programs.

Lessons from activities to convert opium cultivators to legal crops in Pakistan could be applicable to the situation in the Andean countries. The Food and Agriculture Organization (FAO) has been assisting the Pakistani Government for the past 10 years to develop alternative employment for opium cultivators with a focus on increasing production of food crops for national markets. Project funds have been provided by the United Nations International Drug Control Programme and the Government of Pakistan. Production of legal crops in the region (wheat, maize, and pulses) has been increased through the application of improved cultural practices and increased inputs. Cash crops (sugar cane, tobacco, horticultural products, and fodder) were introduced as well, largely through development of irrigation technologies, and the livestock sector was strengthened. A major factor in the success of these efforts was the strengthening of supporting infrastructure, including potable water-supply systems, irrigation networks, and gravel and tarmac roads (38) (chapter 3).

OPPORTUNITY: INCREASE THE VALUE OF AGRICULTURE IN DOMESTIC MARKETS

The value of smallholder agricultural production in the Andean countries is low relative to other sectors. To some degree, this is the result of national food policies that maintain low-cost food for urban areas. In addition, international programs may have adversely affected the prices producers can command in local, regional, and national markets. Food assistance under the P.L. 480 program (the Agricultural Trade Development and Assistance Act of 1954 as amended) provides low-cost food imports to the Andean countries, largely staple crops produced in excess in the United States. Competition with these cheap commodities may have contributed to reduced value of Andean agriculture in the domestic market.



KEVIN HEALY, INTERAMERICAN FOUNDATION

Increasing markets for legal coca products (e.g., coca tea or rnaté de coca) may reduce the hardship for producers adopting alternative crop systems.

OPPORTUNITY: DEVELOP TRANSITIONAL SYSTEMS

Transitional systems that allow coca producers to shift their production systems gradually to legitimate crops may offer an opportunity to ease risk-averse farmers into legitimate agricultural productions systems. While participants in current substitution programs continue to produce some amount of coca, focus remains on coca replacement systems rather than integrated systems. This may have several effects. First, farmers may maintain separate fields for coca and substitution crops, dividing time and effort and potentially reducing yields of the legitimate crops. Secondly, with coca being the "cash crop," farmers are more likely to weight their attention toward the "sure thing' as opposed to the alternative, particularly in times of adversity when yields of both maybe threatened. Lastly, the replacement approach may discourage participation by risk-averse farmers who are unwilling to eliminate coca or by those who do not have sufficient land or labor to tend separate plots. Alternatively, integrated systems that incorporate alternative crops in coca production could provide source reduction benefits as well as improved agronomic attention to legitimate production by the farmer.

OPPORTUNITY: EXPAND MARKETS FOR LEGITIMATE COCA PRODUCTS

Mechanisms to absorb program participants' coca during the transition phase and channel it into legitimate markets offer an opportunity to reduce the coca supply for cocaine production. Options might include expanding the international market for legitimate coca products (e.g., coca tea, pharmaceuticals). However, the large amounts of coca produced are likely to overflow existing legitimate markets.

Alternatively, developing new products from coca may have some merit (61). Potential medicinal and therapeutic applications of coca include: 1) treatment for spasmodic conditions of the gastrointestinal tract, motion sickness, toothache and other mouth sores; 2) caffeine substitute; 3) antidepressant; and 4) adjunct to weight reduction and physical fitness (91). Examination of the other alkaloids found in coca might yield additional industrial possibilities. Although the research and development time required to bring new products to market may reduce the short-term utility of this approach, it could be a useful component in an overall package of efforts to reduce illicit coca production.

Strategy: Intensify Agricultural Product ion

Intensifying agricultural production for domestic and international markets will be necessary for the Andean countries to reduce food imports and produce sufficient quantities of products to interest international markets. This might be done through improving traditional agricultural production systems, facilitating input availability, and reducing disincentives to investment in improved production practices. At least four International Agricultural Research Centers (IARCS) conduct research on crop improvements directly applicable to the Andean region. In fact, many of the advances in staple crop production in the Andean nations have arisen from IARC research efforts (e.g., recent increases in rice and maize yields and production expansion in Peru).

Highly productive forms of agriculture in tropical regions generally focus on some form of polyculture. Improvements in productivity can be generated through carefully planned crop combinations, agroecological suitability, and effective nutrient and energy cycling systems. Integrated systems can be developed that efficiently recycle subsystem by-products through other subsystems, such that the waste from one activity becomes the input to another.

OPPORTUNITY: IMPROVE TRADITIONAL AGRICULTURE SYSTEMS

Traditional production practices developed in the Andean countries could be improved to offer expanded economic benefits for producers. Examination of how these practices promote productivity and sustainability could be used to identify where research and development effort could best be placed. Agroforestry, polyculture, and integrating livestock with agricultural production systems may offer particularly promising opportunities.

Multiple cropping systems have a long history in the Andean region and are ideally suited to the humid tropical zones where crop substitution activities are underway. Agroforestry is of particular interest in substitution programs as many of the alternatives identified are long-cycle tree crops (e.g., tropical fruit trees, nut trees). Currently, only one Consultative Group on International Agricultural Research (CGIAR) institute focuses primarily on agroforestry-the International Council for Research on Agroforestry (ICRAF). ICRAF is located in Kenya, hundreds of kilometers distant from tropical wet forests ecologically similar to those of the eastern Andean foothills and thus these efforts are unlikely to be easily transferred to the Andean countries. Additional agroforestry research was carried out by North Carolina State University at Yurimaguas, Peru. This effort was largely an offshoot of traditional agricultural research, yet it highlighted the importance of perennial tree crops in tropical agriculture. These efforts have ceased, however, largely due to violence in the area.

OPPORTUNITY: DEVELOP SMALLHOLDER AGRICULTURE

Small-scale farms are essentially the rule in coca-producing zones and opportunities to intensify their production are needed. Farming systems could be intensified through the application of modern technology adapted to suit local agroecological conditions. Increasing the availability of agricultural inputs and improving delivery methods may offer an opportunity to intensify agricultural production. Increased productivity at the subsistence level would likely lead to surpluses that could be marketed. Technical assistance exists for many crops and additional work on improved cultivars could increase yields. Assisting smallholders to intensify production may allow them to move gradually to semi-commercial and commercial production. Concomitant with this effort would be strengthening local markets, perhaps to redirect from imports to locally produced commodities.

OPPORTUNITY: ASSIST WOMEN AGRICULTURALISTS

In many regions, women contribute the largest amount of farm work. Yet most efforts to assist farmers have been aimed at men. Traditionally, Latin American women in rural areas have been neglected by development projects (112). Women participate in agriculture in a number of ways, including crop and livestock selection, cultivation, harvest, postharvest handling, and marketing. Significantly, in areas where migration for seasonal labor is common (e.g., High Valleys), women stay at home to care for the crops and livestock. Recently, greater effort has been placed on the role of women in agricultural development, yet, increased efforts could improve the contribution of women farmers in crop substitution programs.

OPPORTUNITY: REMOVE DISINCENTIVES TO INVESTMENT IN IMPROVED SYSTEMS

There are a number of disincentives to investment in agricultural production improvements in the Andean region. These largely stem from national economic and political conditions (e.g., rural poverty, risks to personal security), and most will need to be addressed by national governments. One mechanism open to U.S. and multilateral organizations to improve investment opportunities is to increase the availability and affordability of agricultural credit. Agricultural credit is a key need to improve opportunities for producers to invest in production and land improvements necessary for alternative systems. Coca farmers tend to be small-holders, often without land title, personal capital resources, or access to normal routes of credit. Recent actions on the parts of national governments have improved the outlook for gaining land title, although bureaucratic constraints slow the process.

Within the context of coca substitution programs, opportunities for credit exist. Evidence suggests, however, that insufficient attention has been paid to developing appropriate credit packages for coca farmers. For example, agricultural credit is available to farmers in the Chapare, Bolivia, through an AID grant and is administered through a local private voluntary organization. However, the terms of credit are so high as to make it essentially unavailable for most farmers. Further, in Bolivia credit is conditional on removal of the coca crop, often the sole income-generating activity of the family. Although assistance is provided to develop an alternative production system, income is generally not established until the third year after planting. Yet, repayments for interest are due in year 1 of the loan. Under this scenario it is simple to understand the reluctance to give up coca in exchange for legitimate crops.

Much the same situation exists in Peru where collateral terms are significant (e.g., urban homes) and interest rates vary depending on the credit currency (i.e., 18 percent per year in U.S. dollars and 8 percent per month in Peruvian soles) (122). Although Colombia also lacks agricultural credit for crop diversification for coca, it does provide credit for diversfying coffee. Coffee farmers may receive up to 80 percent of the cost of developing new production sites at 20 percent interest per year. Loan repayment begins with the first harvest and must be completed in 10 years. Delayed payment schedules such as this could likely be appropriate for crop diversification credit.

Issues of credit availability and affordability may increase in importance if substitution becomes more broad-based in order to expand the range of resources exploited. In this case, credit opportunities will be needed for forest, wildlife and wildland, and aquatic resource exploitation—additional activities where producers are likely to be handicapped in meeting existing credit eligibility requirements.

Strategy: Increase the Range of Exploited Renewable Resources

The Andean countries have a wide range of renewable resources that could be developed to increase economic opportunities for producers. While much attention has been placed on narrowly defined agricultural opportunities, less emphasis has been directed toward the potential for expanding sustainable exploitation of other resources such as forests, fisheries, wildlife, or wildlands. Indeed, many coca-growing areas are more suitable to some of these options than traditional agriculture. For example, in the Alto Huallaga, where most coca is produced on steep slopes, agriculture is an environmentally, if not economically, unsuitable alternative. In the Chapare, Bolivia, timber operations were the primary economic activity until the mid-1970s when coca expansion eclipsed the industry (85).

OPPORTUNITY: DEVELOP SUSTAINABLE FORESTRY SYSTEMS

Considerable potential exists to manage Andean forests to increase the flow of benefits to smallholders, and even though deforestation affects an increasing area of these forests, substantial areas of natural forest remain. Efforts to promote protected areas and forest management offer alternative livelihoods and environmental benefits. Opportunities include:

- Conserving biological resources,
- Developing extractive reserves, and
- Developing sustainable timber operations.

The importance of sustaining tropical biological resources has been highlighted in the last two decades and recently was underscored by the United Nations Conference on Environment and Development. One mechanism of conservation has been to cede certain forest areas to indigenous populations to sustain their traditional lifestyles while offering conservation benefits. Similarly, extractive reserves offer economic and conservation opportunities. The value of forest products (nuts, fruits, etc.) harvested from an extractive reserve can be longer-term and significantly higher than that offered by one-time logging operations or conversion to agricultural production (104). Opportunities also exist for ‘chemical prospecting” in tropical forests to identify compounds with commercial potential. Sustainable timber exploitation technologies have been demonstrated in the Palcazu Valley in Peru. Such innovative operations could be tested and adapted to other forest areas in the Andean countries. Despite these potential opportunities, efforts will be needed to increase the understanding of tropical forest management, specifically in the Andean region.

Recently, a cooperative effort between the Nature Conservancy and AID has provided funding (Parks in Peril Project) to ensure protection for threatened national parks in areas of concern. As part of this effort, on-site management will be established in Amboro National Park and Noel Kempff Mercado National Park in Bolivia, La Paya National Park in Colombia, and Pampas del Heath National Sanctuary in Peru. Efforts will include surveying protected area boundaries, recruiting, training, and educating rangers and local communities about park protection, developing park infrastructure, and promoting local community participation (1 13). The AID Environmental Support Project that supports cooperative efforts between foreign organizations and Latin American countries is active in Bolivian forests in conducting botanical inventories (Amboro and Noel Kempff) and developing sustainable harvest for economic tree species. These and similar efforts can contribute to developing national expertise and highlighting opportunities in forest management in the Andean nations.

OPPORTUNITY: DEVELOP SUSTAINABLE WILDLIFE AND WILDLAND MANAGEMENT SYSTEMS

The Andean region has a diverse range of ecosystems supporting a broad variety of wildlife species that are, or might be, managed to offer alternative livelihoods for local populations. Further, wildland management to sustain wildlife populations may offer an additional opportunity to enhance nature-based tourism industries. Development of wildlife resources for national and international markets in wildlife and wildlife products may provide more immediate returns than tourism but could also provide a base for tourism markets.

Wildlife-centered economic development has become more acceptable, and research efforts are being undertaken to determine sustainable yields and appropriate husbandry practices. Some techniques for raising/producing certain wildlife species have been developed and are easily incorporated in rural communities with little capital investment. For example, experimental programs for ranching of green iguanas have now spread from Panama to other neotropical countries (6,127). Licensing and protection mechanisms implemented in the region are making farming and ranching of wildlife more profitable than taking from the wild (97).

The International Union for the Conservation of Nature and Natural Resources and other international resource organizations are working to create viable legal markets for wildlife and wildlife products in conjunction with protecting habitats and wild populations. Congress could support these efforts by providing funding to these organizations to assist the Andean countries to develop wildlife industries. Coordination with AID, UNDCP, and other donors would be necessary to ensure that an adequate support structure was available to handle transport and marketing opportunities for producers.

OPPORTUNITY: DEVELOP SUSTAINABLE FISHERY PRODUCTION SYSTEMS

The numerous Andean lakes and rivers contain a variety of harvestable organisms and, with application of appropriate technology, their productivity could be enhanced. For example, recent fish production in Colombia's Guajira reservoir was 82/kg/ha/yr, whereas sustainable production has been estimated at 103 to 256 kg/ha/yr (134). Similarly, estimates on the productivity potential for the total fishery of Lake Titicaca range from 50,000 to 250,000 metric tons (maximum sustainable yield)--far above current actual yield estimates. Based on a conservative estimate of U.S. $0.50/kg, the fishery resources of Lake Titicaca could realize an annual earning potential of U.S. $25 million (56,60,82,94).

Constraints to developing Andean fisheries include a lack of information on the extent and quality of the various resource systems, level of resource extraction, and fishermen themselves; and shortfalls in handling, processing, and storage technologies and transport infrastructure. Current fishery production is characterized by significant postharvest losses that could be reduced through attention to these needs. For example, postharvest losses from the Pilcomayo fishery are relatively low (9.4 percent) compared with those in the Bolivian highlands (30 percent). The primary difference between these examples is the use of ice in transport from the Pilcomayo fishery (87). Poor handling can reduce the value of fishery products and increase losses to spoilage.

Technical assistance to promote enhanced productivity of existing fisheries will be needed. Introduction of efficient gear and harvest technologies and aquiculture practices to support stocking efforts, training in processing techniques for postharvest handlers, and strengthening of administrative and management protocol for fishery offices are a few of the key needs. Training programs similar to those developed for trout hatcheries in rural communities of Maucana, Peru, could improve local economies through fishery enhancement of lakes and streams (96). Currently, AID does not identify fishery production as a priority for resource development in the Andean region and there is only one fisheries specialist (on loan from National Marine Fisheries Service) in AID (103). AID could increase its effort toward fishery development and establish technical assistance as a priority. A development project costing one to several million dollars could produce a 10-fold increase in total local earning for inhabitants of Lake Titicaca (93).

Alternatively, the Andean countries could take advantage of existing international expertise in aquatic resource management and development. International research organizations, such as the International Center for Living Aquatic Resource

Management (ICLARM), Peace Corps, and other institutions (e.g., International Center for Aquaculture at Auburn University) could be tapped to assist in fishery development or enhancement.

CHAPTER 4 REFERENCES

1. Alcorn, J. B., *Huastec Mayan Ethnobotany* (Austin, TX: University of Texas Press, 1984) In: Gliessman, 1992.
2. Allison, J., *An Ecological Analysis of Home Gardens (Huertos Familiars) in Two Mexican Villages*, M.A. Thesis, Biology, University of California, Santa Cruz, CA, 1983, In: Gliessman, 1991.
3. Altieri, M., *Agroecology: The Scientific Basis of Alternative Agriculture* (Boulder, CO: Westview Press, 1987) In: Gliessman, 1991.
4. Alvarez, A., Agricultural Research Scientist, Advisor to Programa de Desarrollo Alternative Regional, Cochabamba, Bolivia, personal communication, March 1991, In: McCaffrey, 1991.
5. Arbelaez, J., "El Cultivo de Platano en Zona Cafetera, Federation Nacional de Cafeteros, " Bogota, Colombia, 40 p., 1991, In: Villachica, 1992.
6. Ashton, R. E., Jr., "Potential Use of Neotropical Wildlife in Sustainable Development,' contractor report prepared for the Office of Technology Assessment, December 1991.
7. Ashton, R. E., Jr., "Land Use Planning and Ecotourism," *Ecotourism and Resources Conservation* 1:91-98, *1991, In:* Ashton, 1991.
8. Ashton, R. E., Jr., "Handbook on Central American Tourism and Wildlands Protection, ' Paseo Pantera Ecotourism Project, Wildlife Conservation International, 1991, In: Ashton, 1991.
9. Avila, L., Charaja, M., and Camapaza, J. (eds.), ''Socio-Economic Aspects of Fishing the Bay of Puno," unpublished manuscript, In: Schroeder, 1992.
10. Bayley, P. B., "Fish Resources in the Palcazu Valley: Effects of the Road and Colonization on Conservation and Protein Supply," Report to USAID/Peru, JRB Associates, McLean, VA, 1981, In: McCaffrey, 1991.
11. Bedoya, E., "Las Causes de Deforestation en la Amazonia Pruana: Un Problema Estructural," Working Paper No. 46 (Binghamton, NY: Institute for Development Anthropology, 1990) In: Painter and Bedoya, 1991.
12. Bedoya, E., Intensification and Degradation in the Agricultural Systems of the Peruvian Upper Jungle, " *Lands at Risk in the Third World*, P.D. Little and M.M. Horowitz (eds.) (Boulder, CO: Westview Press, 1987) In: Painter and Bedoya, 1991.
13. Beissinger, S.T., and Bucher, E. H., "Can Parrots Be Conserved Through Sustainable Harvesting?" *Bioscience* 42(3):164-172, March 1992.
14. Bonetto, A, "Report on the Lirnnological Studies To Be Carried out in the Amazon of Peru, ' FAO Project PNUD/FAO-PER/76/022, Part 4, *Informacion de Institute del Mar de Peru* 81: *173-205, 1981, In:* Schroeder, 1992.
15. Boo, E., ''Ecotourism: The Potentials and the Pitfalls," World Wildlife Fund, Washington, DC, 1990, In: McCaffrey, 1991.
16. Boyer, J. S., "Plant Productivity and Environment,'' *Science* 218:443-448, Oct. 29, 1982.
17. Brack, A., "EcologicalEvaluation of the Palcazu River Valley (Pasco, Peru) and Guidelines for Environmental Conservation Program, Report to USAID/Peru, JRB Associates, McLean, VA, 1981, In: McCaffrey, 1991.
18. Brockman, C.E. (cd.), ''Perfil Ambiental de Bolivia,' USAID, La Paz, Bolivia, International Institute for Environment and Development, Washington, DC, 1986, In: McCaffrey, 1991.
19. Browder, J. O., "The Limits of Extractivism," *Bioscience* 42(3):174-182, March 1992.
20. Brylinsky, M., and Mann, K., "An Analysis of Factors Governing Productivity in Lakes and Reservoirs," *Limnology and Oceanography* 18: *1-13, 1973, In:* Schroeder, 1992.
21. Budowski, G., "Home Gardens in Tropical America: A Review," paper presented at the First International Workshop on Tropical Homegardens, Bandung, Indonesia, Dec. 2-9,1985, In: Gliessman, 1991.
22. Chavez, A., ''Andean Agricultural Research and Extension Systems and Technology Transfer Activities: Potential Mechanisms To Enhance Crop Substitution Efforts in Bolivia, Colombia, and Peru, ' contractor report prepared for the

Office of Technology Assessment, December 1991.
23. Christanty, L., *An Ecosystem Analysis of West Javanese Homegardens*, East-West Center, Honolulu, HA, working paper, 1981, In: Gliessman, 1991.
24. Christanty, L., Abdoellah, O., Marten, G., and Iskander, J., "Traditional Agroforestry in West Java: The Pekarangan (Homegarden) and Kebun-talun (Annual-Perennial Rotation) Cropping System," In: Marten, G. (cd.), *Traditional Agriculture in Southeast Asia* (Boulder CO: Westview Press, 1986) In: Gliessman, 1992.
25. Conway, P., ''Silk for Life-Project Proposal,' Silk for Life, Madison, WI, January 1991.
26. Coutts, R., and Zuna, F., "Present State of Fishery Technology in Bolivia," Departamento Nacional Desarrollo Pescadero, La Paz, Bolivia, 1981, In: Schroeder, 1991.
27. Crutchfield, T., Owner, Reptile Enterprises, Bushnell, FL, personal communication, 1991, In: Ashton, 1991.
28, Darschnik, S., and Shuhmacher, H., "Trout Farms Causing Disturbance in the Natural Stream Continuum," *Archeological Hydrobiology* 110:409-439, 1987, In: Schroeder, 1992.
29. DENG, Hanseng (Guangzhou Institute of Geography), "Application of Dike-Pond Systems to the Degraded Lands in South China, " Paper Submitted at the China Tropical Lands Workshop, 9-13 September, 1991, University of Hong Kong, Kadoorie Agricultural Centre, Shek Kong, New Territories, 1991.
30. Development Alternatives, Inc., 'Environmental Assessment of the Chapare Regional Development Project, Bolivia, ' DAI, Bethesda, MD, 1990, In: Stevenson, 1992.
31. Deza, A., "Incubation of Eggs of Kingfish *Basilichthus bonariensis* in Cuzco,'' *Hydrobios* 9(1-2):24-28, *1985, In:* Schroeder, 1992.
32. Dourojeanni, M., ''Amazonia Que Hacer?' Centro de Estudios Tecnologicos de la Amazonia, Iquitos, Peru, 1990, In: McCaffrey, 1991.
33. Dourojeanni, M., ''Fauna and Wild Area Management in the Palcazu Valley, ' Report to USAID/ Peru, JRB Associates, McLean, VA., 1981, In: McCaffrey, 1991.
34. ECONSULT, ''Informe Final de la Evaluation del Proyecto USAID No. 572-0244 Desarrollo Rural del Alto Huallaga, " Lima, Peru, 1986, In: Painter and Bedoya, 1991.
35. Edwards, S. R., Coordinator, IUCN Sustainable Use of Wildlife Initiative, Washington, DC, personal communication, 1991, In: Ashton, 1991.
36. Everett, G., "The Rainbow Trout *Salmo fairdneri* (Rich.) Fishery of Lake Titicaca, *Journal of Fishery Biology* 5:429-440, *1973, In:* Schroeder, 1991.
37. Everett, G., "The Rainbow Trout of Lake Titicaca and the Fisheries of Lake Titicaca,'' Report to the Government of Peru, 1971, In: Schroeder, 1992.
38. Food and Agriculture Organization, *FAO in Action* vol. *43,* Jan./Feb. 1987.
39. Foster, R, B., ''Brief Inventory of Plant Communities and Plant Resources in the Palcazu Valley, Peru,' Report to USAID/Peru, JRB Associates, McLean, VA., 1981, In: McCaffrey, 1991.
40. Francis, C. A., *Multiple Cropping Systems (New* York, NY: McMillan, 1986).
41. Franzin, W., and Harbicht, S., "An Evaluation of the Relative Success of Naturalized Brook Charr, Salvelinum fontinalis, populations in South Duck River and Cowan Creek, Duck Mountain Region" *Manitoba Canada Technical Report on Fisheries and Aquatic Science 1370,25* p., 1985, In: Schroeder, 1992.
42. Gibson, H., "Lake Titicaca," *Verh. International Vercin. Limnological* 15:1 *12-127, 1964, In:* Schroeder, 1992.
43. Gliessman, S., "Diversification and Multiple Cropping as a Basis for Agricultural Alternatives in Coca Producing Regions, " contractor report prepared for the Office of Technology Assessment, February 1992.
44. Gliessman, S. R., ' 'Integrating Trees Into Agriculture: The Home Garden Agroecosystems as an Example of Agroforestry in the Tropics, ' Gliessman, S.E. (cd.), *Agroecology: Researching the Ecological Basis for Sustainable Agriculture (New* York, NY: Springer Verlag Ecological Studies Series, 1990) pp. 160-168.
45. Gliessman, S, R., ''Plant Interactions in Multiple Cropping Systems," In: Francis, C.A. (cd.)

Multiple Cropping Systems (New York, NY: McMillan, 1986) In: Gliessman, 1992.

46, Gliessman, S. R., Garcia, R., and Amador, M., “The Ecological Basis for the Application of Traditional Agricultural Technology in the Management of Tropical Agroecosystems, ' *Agro-Ecosystems* 7:173-185, *1981, In:* Gliessman, 1992.

47. Gomez-Pompa, A., “On Maya Silviculture,'' *Mexican Studies* 3:1-17, *1987,* In: Gliessman, 1992.

48. Gonzalez Jacome, “Homes Gardens in Central Mexico,' 1.S. Barrington (cd.) *Prehistoric Intensive Agriculture in the Tropics,* BAR International Series 232, Oxford England, 1985, In: Gliessman, 1992.

49. Goodland, R.J.A., Watson, C., and Ledec, G., *Environmental Management in Tropical Agriculture* (Boulder, CO: Westview Press, 1984) In: Gliessman, 1992.

50. Gow, D., Clark, K., Earhart, J., Fujita, M., Laarman, J., and Miller, G., “Peru An Assessment of Biological Diversity, ' USAID, DESFIL, Washington, DC, 1988, In: McCaffrey, 1991.

51. Henson, T., Owner, Tropical Wildlife, Ltd., Suriname, personal communication, 1991, In: Ashton, 1991.

52, Hoffman, M. S., *The World Almanac and Book of Facts 1991 (New* York, NY: Pharos Books, 1990), In: Schroeder, 1992.

53. INADE-APODESA, ‘Manejo de Bosques Naturales de la Selva Alta del Peru: Un Estudio de Caso del Vane del Palcazu,” Instituto Nacional Desarrollo—Asistencia a la Politica de la Selva Alta, USAID Conco Consulting Corporation, Tropical Science Center, Lima, Peru, 1990, In: McCaffrey, 1991.

54. *International Ag-Sieve*, “Tropical Rain forest Plants: The Bottom Line,” 5(1):3, 1992.

55. Janzen, D. H., ‘‘TropicaJ Agroecosystems,” *Science* 182: 1212-1219, 1973, In: Gliessman, 1992.

56. Johanesson, K., Vilchez, R., and Bertone, D., “Acoustic Estimation of Icthyomass and its Distribution in Lake Titicaca, ” FAO Report FAO/GCP/RLA/025 (NOR), 1981, In: Schroeder, 1991.

57. Kass, D. C. L., ‘‘Polyculture Cropping Systems: Review and Analysis, ” *Cornell International Agriculture Bulletin* 32:1-69, *1978.*

58. Kaye, M., President, Costa Rica Expeditions, San Jose, Costa Rica, personal communication, 1991, In: Ashton, 1991.

59. Kozel, S. and Hubert, W. , “Testing of Habitat Assessment Models for Small Trout Streams in the Medicine Bow National Forest, Wyoming,' *North American Journal of Fishery Management* 9:458-464, *1989, In:* Schroeder, 1992.

60. Laba, R., “Fish, Peasants, and State Bureacracies: The Development of Lake Titicaca, ' *Comparative Political Studies* 12:335-361, *1979,* In: Schroeder, 1991.

61. Latin America and Caribbean Commission on Development and Environment, *Our Own Agenda*, Inter-American Development Bank, United Nations Development Programme, p. 38-39, 1989

62. Leaky, R., Director, Kenya Wildlife Protection, Nairobi, Kenya, personal communication, 1991, In: Ashton, 1991.

63. LeVieil, D., “Territorial Use-Rights in Fishing ('TURFS) and the Management of Small-Scale Fisheries: The Case of Lake Titicaca (Peru), PhD Dissertation University of British Columbia, Canada, 1987, In: Schroeder, 1992.

64. LeVieil, D., and Orlove, B., “Local Control of Aquatic Resources: Community and Ecology in Lake Titicaca, Peru, ” *American Anthropology 92, 1990, In:* Schroeder, 1992.

65. LeVieil, D., and Orlove, B., ‘‘Socio-Economic Importance of Lake Titicaca Macrophytes,” unpublished manuscript, In: Schroeder, 1992.

66. Lightfoot, C., Integration of Aquiculture and Agriculture: A Route to Sustainable Farming Systems, *International Ag-Sieve 4(5):4-5, 1992.*

67. Lin, S., Shy, J., Yu, H., “Morphological Observation on the Development of Larval Machrobracium asperulum (Crustacea, Decapoda, Palaemonidae) Reared in the Laboratory, ' *Journal of Fisheries Society* Taiwan. 15:8-20, 1988, In: Schroeder, 1992.

68. Lindbergh, K., ‘‘Policies for Maximizing Nature Tourism's Ecological and Economic Benefits,” World Resources Institute, Washington, DC, 1991, In: Ashton, 1991.

69. Little, E., "Handbook of Utilization of Aquatic Plants,' FAO Fishery Technical Paper (1 87): 176 p., 1979, In: Schroeder, 1992.

70, Mares, M. and Ojeda, R., ''Faunal Commercialization and Conservation in South America, ' *Bioscience* 34:580-584, *1984*, In: Ashton, 1991.

71. McCaffrey, D., "Biodiversity Conservation and Forest Management as Alternatives to Coca Production in Andean Countries, " contractor report prepared for the Office of Technology Assessment, August 1991.

72. McGrath, D. G., *The Animals Products Trade in the Brazilian Amazon* (Washington, DC: National Wildlife Federation, 1986), In: Ashton, 1991.

73. McNeely, J. A., "Economics and Biological Diversity: Developing and Using Economic Incentives To Conserve Biological Resources, ' International Union for the Conservation of Nature and Natural Resources, Gland Switzerland, 1988, In: McCaffrey, 1991.

74. Medina-Pizzali, A., "Small-scale Fish Landing and Marketing Facilities, ' FAO Fishery Technical Paper, 291 :68, 1988, In: Schroeder, 1992.

75. Ministeno de Agricultural, "Plan Nacional de Accion Forestal 1988 -2000," Lima Peru, 1987, In: McCaffrey, 1991.

76. Myers, N., ''Discounting Depletion: The Case of Tropical Forests, " *Futures* December 1977, In: McCaffrey, 1991.

77. Nagoshi, M. and Kurita, H., ''Relationship Between Population Density and Production of the Redspot Masu-Trout Oncorhynchus rhodurus in Japanese Mountain Stream,' *Bulletin of the Japanese Society of Fisheries* 52:1 *875-1879, 1986*, In: Schroeder, 1991.

78. Ninez, V. "Introduction: Household Gardens and Small Scale Food Production, ' *Food and Nutrition Bulletin 7(3):1-5, 1985 In:* Gliessman, 1991.

79, Norton, G., and Ganoza, V., "The Benefits of Agricultural Research and Extension in Peru, " NCSU/AID, Lima, Peru, 1985, In: Chavez, 1991.

80. Organization of American States, "Minimum Conflict: Guidelines for Planning the Use of American Humid Tropical Environment s,' Washington, DC, 1987, In: McCaffrey, 1991.

81. Orlove, B., "Barter and Cash Sale on Lake Titicaca: A Test of Competing Approaches,' *Current Anthropology* 27:85-98, *1986, In:* Schroeder, 1992.

82. Orlove, B., LeVieil, D., and Trevino, H., "Social and Economic Aspects of the Lake Titicaca Fisheries,' unpublished manuscript, 1990, In: Schroeder, 1992.

83. Orlove, B., and LeVieil, D., "Some Doubts About Trout: Fisheries Development Projects in Lake Titicaca," In: B. Orlove, M. Foley, and T. Love (eds.) *State, Capital, and Rural Society: Anthropological Perspectives on Political Economy in Mexico and the Andes* (Boulder CO: Westview Press) 1989, In: Schroeder, 1991.

84. Painter, M,, Institute forDevelopmentAnthropology, Binghamton, New York, personal communication, October 1991.

85. Painter, M., and Bedoya-Garland, E., "Institutional Analysis of the Chapare Regional Development Project (CRDP) and the Upper Huallaga Special Project (PEAH),'' contractor report prepared for the Office of Technology Assessment, July 1991.

86. Parenti, L., "A Taxonomic Revisionof the Andean Killifish Genus *Orestias* (Cyprinodontiformes, Cyprinodontidae), *Bulletin of the American Museum of Natural History* 178: *107-214,* 1984, In: Schroeder, 1992.

87. Pattie, P. S., Arledge, J., Asmon, I., Avram, P., Castilla, O., Gertsch, M., Kraljevic, I., Riordan, J., and Smith, J., *Agriculture Sector Assessment for Bolivia*, prepared for Agriculture and Rural Development Office USAID/Bolivia Mission, IQC Contract Number PDC-1406-1-00-7007 (Washington, DC: Chemonics International Consulting Division, January 1988).

88. Paz, S., Sociology Student, Universidad May San Sirnon, Cochabamba, Bolivia, personal communication, March 1991, In: McCaffrey, 1991.

89. Perez, C., Advisor to Programa Desarrollo Alternativo Regional, Cochabamba, Bolivia, personal communication, March 1991, In: McCaffrey, 1991.

90. PerI, M. A., Kiernan, M. J., McCaffrey, D., Buschbacher, R. J., and Batmanian, G. J., "Views for the Forest: Natural Forest Management Initia-

tives in Latin America, ' World Wildlife Fund, Washington, DC, 1991, In: McCaffrey, 1991.

91. Plowman, T., "Coca Chewing and the Botanical Origins of Coca (*Erythroxylum* ssp.) in South America," D. Pacini and C. Franquemont (eds.), *Coca and Cocaine: Effects on People and Policy in Latin America,* cultural Survival Report *#23* (Peterborough, NH: Transcript Printing Company, 1986), pp. 5-33.

92. Repetto, R. ''The Forest for the Trees? Government Policies and the Misuse of Forest Resources," World Resources Institute, Washington, DC, 1988, In: McCaffrey, 1991.

93. Richerson, P., Professor, Aquatic Ecologist, Institute of Ecology, University of California—Davis, personal communication, 1991, In: Schroeder, 1991.

94. Richerson, P., Widmer, C., and Kittel, T., "The Limnology of Lake Titicaca (Peru-Bolivia), a Large, High Altitude Lake," University of California Davis Institute of Ecology Publication, 14:78, 1977, In: Schroeder, 1991.

95. Rincon, O., "El cultivo de Macadamia, Federacion Nacional de Cafeteros,'' Bogota, Colombia, 29 p, 1990, In: Villachica, 1992.

96. Rodriguez, A., ''Pisciculture program in the 'Central de Capacitation' for work in San Juan Bautista, Matucana, Peru,' Documenta 10:8-13, 1982, In: Schroeder, 1991.

97. Ross, P. R., Executive Officer, Crocodile Specialist Group, personal communication, 1991, In: Ashton, 1991.

98. Ruthenberg, H., *Farming Systems in the Tropics,* revised edition (Oxford: Clarendon, 1980) In: Gliessman, 1992.

99. Ryel, R., ''Ecotourism: An Economic Alternative for Natural Resource Destruction, " *Ecotourism and Resource Conservation* 1:31-44, *1991* Miami FL, In: Ashton, 1991.

100. Sanchez, P., and Benites, J., "Opciones Tecnologicas para el Manejo Racional de Suelos en la Selva Peruana," 1st Symposium on the Humid Tropics, Belem do Para, 1986, In: Chavez, 1991.

101 Schroeder, R., "Fishery/Aquatic Resources in Bolivia, Colombia, and Peru: Production Systems and Potential as Alternative Livelihoods, " contractor report prepared for the Office of Technology Assessment, October 1991.

102. Shaw, J.H., ''The Outlook for Sustainable Harvests of Wildlife in Latin America,' *Neotropical Wildlife Use and Conservation* (Chicago, IL: Chicago University Press, 1991) In: Ashton, 1991.

103. Simmons, K.E., Executive Vice President, RDA International, Inc., personal communication 1991, In: Schroder, 1991.

104. Smith, E., "Growth vs. Environment," *Business Week* May 11, 1992, pp.66-75.

105. Stevenson, B. McD., "Post-Harvest Technologies to Improve Agricultural profitability," contractor report prepared for the Office of Technology Assessment, March 1992.

106. Terborgh, J., Emmons, L. H., and Freese, C., ' 'La Fauna Silvestre de la Amazona: El Despilfarro de un Rescurso Removable, " V. de Lima 46:77-85, 1986, In: Ashton, 1991.

107. Thomsen J. B., and Brautigam, A., "Sustainable Use of Neotropical Parrots,' *Neotropical Wildlife Use and Conservation* (Chicago, IL: Chicago University Press, 1991) In: Ashton, 1991.

108. Tosi, J. A., Jr., "Integrated Sustained Yield Management of Primary Tropical Wet Forest: A Pilot Project in the Peruvian Amazon,' Tropical Science Center, Costa Rica, 1991, In: McCaffrey, 1991.

109. Tosi, J. A., Jr., "Ecological Analysis and Land Use Capacity in the Area of the Chapare Project," Report to USAID/Bolivia, Cochabamba, Bolivia, 1983 In: McCaffrey, 1991.

110. Tosi, J. A., Jr., ''Sustained Yield Management of Natural Forests," Forestry Sub-Project, Central Selva Resources Management Project, Palcazu Valley, Peru, Tropical Science Center, San Jose, Costa Rica, 1982, In: McCaffrey, 1991.

111. Trenbath, B. C., ''Biomass Productivity of Mixtures, *Advances in Agronomy* 26:177-210, *1974, In:* Gliessman, 1992.

112. United Nations, UNIFEM, ''Action for Agenda 21," United Nations, New York, New York, 1991.

113. U.S. Agency for International Development, "Tropical Forests and Biological Diversity—USAID Report to Congress 1990-1991," USAID, Washington, DC, May 1992.

114. U.S. Agency for International Development, "The Palcazu Valley (Oxapampa - Peru), Land

Use Planning for Sustained Development, An Experience Applicable to the Amazon Region,' Ronco Consulting Corporation, Washington, DC., 1989, In: McCaffrey, 1991.

115. U.S. Congress, Office of Technology Assessment, Crop Substitution Workshop, Sept. 30-Oct.1, 1991, Washington, DC.

116. U.S. Congress, Office of Technology Assessment, *Integrated Renewable Resource Management for U.S. Insular Areas,* OTA-F-325 (Washington, DC: U.S. Government Printing Office, June 1987).

117. Unruh, J.D, "Iterative Increase of Economic Tree Species in Managed Swidden-Fallows of the Amazon," *Agroforestry Systems 11(2):175-197, 1990.*

118. Valderrama, M., and Zarate, M., "Some Ecological Aspects and Present State of the Fishery of the Magdalena River Basin, Colombia, South America, ' *Proceedings of the International Large River* Symposium 106:409-421, 1989, In: Schroeder, 1992.

119. Vaux, P., Wurtsbaugh, W., Trevino, H., Marine, L., Bustamente, E., Torres, J., Richerson, R., and Alfaro, R., "Ecology of the Pelagic Fishes of Lake Titicaca, Peru-Bolivia," *Biotropica* 20:220-229, 1988, In: Schroeder, 1992.

120. Vegas-Valez, M., Ruiz, L., Vega, A., and Sanchez, S., ''The Shrimp *Chryphiops caementarius* (Palaemonidae): Embryonic Development, Stomach Content, and Controlled Reproduction: Preliminary Results," *Review of LatinoAmerican Aquaculture* 9:1*1-28, 1981,* In: Schroeder, 1992.

121. Vegas-Valez M., Ruiz, L., Vega, A., and Sanchez, S., ''The River Prawn Chryphiops caementarius (Palaemonidae): Embryonic Development, Stomach Content and Reproduction Under Laboratory Conditions, Preliminary Note, Summaries Workshop of Natural Sciences, 1980, In: Schroeder, 1992.

122. Villachica, H., ''Crop Diversification in Bolivia, Colombia, and Peru: Potential to Enhance Agricultural Production, ' contractor report prepared for the Office of Technology Assessment, April 1992.

123. Villachica, J., Lescano, C., Lazarte, J., Chumbe, V., Estudio de oportunidades de inversion en desarrollo e industrialization de cultivos tropicales en Pucallpa. Perfil de proyecto para la planta de coloantes naturales yu para la planta de conservas de palmito, Convenio FUNDEAGRO, Region Ucayali, Lima Peru, 1992.

124. Welcomme, R., ''River Fisheries,' FAO Fishery Technical Paper, (262):330 p., 1985, In: Schroeder, 1992

125. Welcomme, R., "River Basins," FAO Fishery Technical Paper, (202):60 p., 1983, In: Schroeder, 1992.

126. Welcomme, R., and Henderson, H., ' 'Aspects of the Management of Inland Waters for Fisheries," FAO Fisheries Technical Paper (161):36 p., 1976, In: Schroeder, 1992.

127. Werner, D. I., "The Rational Use of Green Iguanas, ' *Neotropical Wildlife Use and Confervation* (Chicago, IL: Chicago University Press, 1991) In: Ashton, 1991.

128. Willey, R. W., "Intercropping-Its Importance and Research Needs. Part 1. Competition and Yield Advantages,' *Field Crops Abstracts* 32:*1*-10, 1979, In: Gliessman, 1992.

129. Winterbottom, R., "Taking Stock: the Tropical Forestry Action Plan After Five Years," World Resources Institute, Washington, DC, 1990, In: McCaffrey, 1991,

130. World Resources Institute, *World Resources 1990-1991: A Guide to the Global Environment* (Oxford: Oxford University Press, 1990), In: McCaffrey, 1991.

131. World Resources Institute, International Institute for Environment and Development, *World Resources 1986: An Assessment of the Resource Base that Supports the Global Economy (New* York: Basic Books, Inc., 1986) In: McCaffrey, 1991.

132. Wurtzbaugh, W., Associate Professor, Fisheries Biologist, Department of Fisheries and Wildlife/ Ecology Center, Utah State University, personal communication, September 1991.

133. Wright, M., "Selling Timber without Selling Out,' *Tomorrow: The Global Environment Magazine* 1(2):87, *1991.*

134. Zarate, V. Valderrama, B., Sanchez, M., and Martinez, R., ''Evaluation of the Fisheries of the Guajiro Reservoir and Some Management Criteria, " *Trianea* 3:215-226, *1989, In:* Schroeder, 1991.

135. Zhou, W., "A Preliminary Report on the Introduction and Utilization of Blue Algal Bloom in Some Lakes of Our Country (China)," *Trans-Atlantic Oceanoligical Limnology* 4:54-57, *1987,* In: Schroeder, 1991.