SPECIAL ISSUE

# SUSTAINABILITY

## Notes for Discussion

# SUSTAINABILITY IN CIAT'S RESEARCH PROGRAMME

## SUSTAINABILITY AS AN ISSUE

- On a global basis, cereal production per capita in the last three decades has increased at an annual growth rate of 2.7%, enough to meet increasing demands caused by population growth, higher intake in developing countries, and growing needs for animal feed in the developed world.

- Increased productivity can be mainly attributed to technological innovations in both the "industrial" and the "green revolution" agriculture, mainly as a result of:
  - o. new high yielding varieties
  - o. more use of agrochemicals
  - o. larger irrigated area

- In spite of this remarkable achievement, growth has not been equitable in its impact. On absolute terms, there are more hungry people in the world today than ever before in human history, with 7-800 million people still undernourished.

- The impacts of new technology have been uneven, and in some respects the agricultural technology gap has widened. It is well accepted that the so-called "green revolution" has bypassed Africa. Global agriculture has the potential to grow enough food for all, but food is not always available where needed. On a global basis then, shifting food production to food-deficit countries would be a way to mitigate this uneven food distribution.

- Agricultural development, however, should not be measured only as more food, but also as more opportunities for people to earn money to purchase food. Subsidizing food exports in the developed world and the corresponding importation by developing countries with untapped resources may lead to unemployment in the latter. This marginalizes people, who are then forced to destroy the resource base to survive, and thus affecting sustainability.

- Important as these macro-elements are in assessing the impact of modern technologies, IARCs direct area of influence is closer to that of national research systems and the farming community. In this context, the technology behind increases in agricultural productivity in resource-rich systems has not been adopted at similar rates by resource-poor farmers, that rely on uncertain rains and are usually based upon fragile soils in difficult-to-farm areas: highlands, drylands and forests.

- Population growth, lack of adequate technologies and few economic incentives push these traditional systems either onto marginal lands, wherever available, or into higher pressures on resources that break the state of equilibrium. Both paths lead to overexploitation of the land and the consequent degradation of natural resources.

- Under these circumstances, it seems that we should be concerned with the impacts of adoption of CIAT technologies on degradation of soils, water regimes, atmosphere, and forests and upon the economic prospects of agricultural development. Such economic prospects are certainly influenced by many off-farm conditions of an economic, sociological, political and institutional nature, so we should probably not concentrate our attention only on the ecologically oriented aspects of sustainability. It could be concluded then that sustainability is a technically and socially relevant issue to be incorporated into our institutional value system.

- In addition to these sound technical reasons, developments in our "institutional environment" would also indicate the convenience of giving greater emphasis to sustainability considerations. In a recent letter to the CGIAR Secretariat a U.S.A.-based Committee on Sustainable Agriculture for Developing Countries (28 leading environmental organizations from that country) state: "In closing, we would like to stress the importance - indeed the urgency - of the centers doing more effective work to get the story of their accomplishments out to political and opinion leaders in donor countries, particularly the United States. The United States Congress, faced with a budget crisis, will certainly be tempted to continue to cut support for the Agency for International Development, and that in turn could well result in more cuts for the centers. American budget cuts furthermore could well result in a cascade of cuts by other donors, a situation that we would all deplore"

OBJECTIVE OF THE SESSION

- To set out a process aimed at defining an institutional position on what sustainability concerns are relevant to CIAT and how are they going to be incorporated in our research and training activities, vis-a-vis the coming quinquennial review.

- The main purpose of our presentation is to raise relevant topics for discussion, hoping that it will help designing the process to follow.

DEFINITIONS

- It is appropriate to first differentiate between stability and sustainability. According to Conway (1985), the former is given by the degree to which productivity is constant in the face of small disturbances caused by the normal fluctuations of climate and other environmental variables; while sustainability is the ability of a system to maintain productivity in spite of a major disturbance, such as caused by intensive stress or a large perturbation. Traditional shifting cultivation systems generally have low stability, but high sustainability.

- According to TAC (1986), a "dictionary" definition would suggest that agricultural systems would be sustainable if production could be maintained at current levels, a concept considered to be static. They see sustainability as a dynamic concept, reflecting changing needs, and propose the following definition:

  "Sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the natural resource base and avoiding environmental degradation".

- The TAC definition would imply that the satisfaction of human needs has no limits. The concept of sustainability, however, does imply limits, i.e., limitations imposed by the present state of technology and social organization on the use of environmental resources, and their ability to absorb the effects of human activities.

- It could be said that so far the issue of sustainability has been mainly raised as a set of concerns about different aspects related to the generation of agricultural technologies, such as:

  + loss of genetic diversity
  + soil degradation
  + deforestation
  + desertification
  + impact of agrochemicals
  + development policies

+ marginalization (loss of income, employment) of semilandless rural people.
+ institutional continuity (NARIs)

- In developing the subject the Team has actually elaborated on some of these concerns, as they could affect a range of components of farming systems, from the plant to an ecosystem, going through a natural resource, soils, and the actual farming system, ultimate beneficiary of our activities. We are hopeful that by taking this aggregative approach the discussion will look at sustainability from different angles of our research for development activities in CIAT.

F.TORRES: 27/1/88

# GENETIC DIVERSITY AND YIELD STABILITY

I. Modern Agricultural Research may impact upon the genetic diversity of a cropping system or crop species in several ways.

A. Narrowing of species components.

  1. Mixed cropping --> monoculture
  2. Multi-component wild mixture --> few components, managed mixture
     a. Forest --> Agroforestry
     b. Native savanna --> Pasture

B. Reduction of genetic variability within crop.

  1. Habitat destruction with loss of wild populations (e.g. Manihot spp.).
  2. Replacement of land races by a few closely related varieties (e.g. Beans in Latin America).
  3. Tissue culture techniques.
     a. Only certain genotypes/cytoplasm amenable to the techniques.
     b. Doubled haploids --> eliminates residual segregation

II. INFLUENCE ON YIELD STABILITY AND RELEVANCE (Why ~~may~~ reduced genetic variability may pose a problem?)

A. Reduction of plasticity to respond to short-term perturbations.

  1. Weather (drought, excessive rainfall etc.).
  2. Pest/pathogen complexes.

B. Reduced ability to respond to medium, and long-term shifts.

  1. Climatic changes
  2. Socioeconomic changes
     a. Shifts in input availability
     b. Consumer preferences

c. Technification of demand

i. human comsumption --> animal consumption

ii. direct consumption --> processing

III. SOCIAL CONCERNS

A. Most production coming from a narrow genotype may exclude certain sectors of population.

1. Producers on marginal lands not suited to the predominant type
2. Producer without economic resources to support the predominant type
3. Eliminate certain regions as production center

B. Standardize market --> more equitable

C. Synchronous harvests

1. Exagerate price fluctuations
2. Favor farmers with on-farm storage (await higher prices)

IV. HISTORICAL PERSPECTIVES

A. "Genetic" uniformity considered to be the culprit in severe yield perturbation.

1. Irish potato famine (probably) (1844).
2. Southern corn leaf blight epidemic USA (1970).
3. Various tungro/brown plant hopper epidemics ASIA (Post-1965)
4. HBV epidemic Colombian rice (1982)

B. Land races or genetic diversity are not panaceas.

1. Long before modern crop improvement "reduced" diversity, disease, pestilence, natural calamities caused crop failures and famine.

C. Notable examples from modern agricultural where genetic diversity either did not or could not protect against severe perturbation.

1. Dutch elm disease of American elm and American Chestnut blight (introduce pathogen of very diverse, out-pollinated spp.).
2. S. American leaf blight of rubber in Brazil (native pathogen and highly variable host placed in uniform environment).
   a. Note that mono culture of very narrow genetic base in Asia has been stable.
3. S. corn leaf blight - no amount of genetic diversity would have had much effect, if Tms cytoplasm present.

D. Some natural systems have little species diversity yet are ± stable.

1. Coniferous forests of northern hemisphere.
2. Eucalyptus forests of Australia.

V. GENETIC DIVERSITY AND YIELD STABILITY WITHIN CONTEXT OF CIAT COMMODITIES

A. Rice

1. Problems identified by Program.
   a. Perhaps most vulnerable as it is most advanced in breeding
   b. Irrigated rice adds uniform environment to genetic uniformity
   c. Cytoplasm of virtually all modern rice in world is identical
   d. Track record poor in terms of disease/insect stability of modern rice
2. Solutions
   a. Program aware of issue and has taken and will continue to take steps to addressing it.
      i. is opening cytoplasm to include traditional African Upland
      ii. exploring techniques to permit rapid broadening of nuclear genetic base

iii. characterizing material to better identify and quantify variability

iv. Dispatching earlier segregating material to national programs --> local selections --> lower probability of single line predominating over wide area.

B. Tropical Pastures

1. Problems identified by Program.

a. Reduction of native, highly diverse pasture to just a few spp. (loss of woody plants as well).

b. Increased stocking rates made possible by strategic exploitation of improved pastures --> pressure on native pasture --> overgraze some spp. to exclusion or even local extintion.

c. Brachyaria and spittle bug.

d. Tropical forest (See relevant section).

2. Solutions

a. Limit area converted to improved pastures.

b. Clear strategic management practices.

c. Offer alternative improved pastures components.

C. Cassava

1. Problems

a. Habitat destruction for wild spp.

b. Clonal propagation --> risk of narrow base (especially in Asia and Africa).

2. Solutions

a. Dispatch of F1 seed for local evaluation.

b. Conservation of wild and cultivated types (tissue culture and bank).

D. Beans

1. Problems

a. I-gene

b. Breeding strategy seems to favor vertical and race specific resistance.

c. Extensive genetic diversity in Latin America may be at risk with coverage by a few closely related lines.

d. Unusual to grow in monoculture and risk shift with highly suscessful varieties.

2. Solution

a. Diverse resistance sources

b. Natural epidemic breeding (hot spot)

c. Collection and bean bank

d. Varietal mixtures as specific strategy

VI. CONTRIBUTION OF INTERNATIONAL AGRICULTURAL RESEARCH CENTERS TO GENETIC DIVERSITY

A. Collection and preservation of germplasm

B. Wide crosses

C. International exchange of germplasm (Local native cultivars may be quite narrow)

D. Crosses among land races previously reproductively isolated

E. Application of biotechnology to tropical crops of little economic importance to developed countries

# IS THE SMALL FARM SUSTAINABLE?
## Implications for CIAT

I. Factors leading to the degeneration of small farm systems:

1. The traditional small farm in low income countries:

   - A relatively closed system (self-sustaining) for recycling energy/nutrients; in equilibrium.
   - Farmers' practices close to the optimum, given existing constraints and resources.
   - Functional base of traditional (or indigenous) technology and knowledge.

2. As population growth increases, this traditional equilibrium begins to break down:

   - Farm sizes decline (division through inheritance).
   - Soil fertility declines; as maximum carrying capacity of the land is reached, farmers mine the land; deforestation occurs; pastures are overgrazed.
   - Agricultural involution may occur; increasing amounts of labor are required to maintain a given level of productivity.
   - Desequilibrium appears: traditional practices have to adapt to changing resource constraints.
   - Nutritional standards decline (cheap staples are substituted for higher value foodstuffs, protein sources).
   - Internal sustainability of the domestic unit is threatened by outmigration, especially of the young or of males; - feminization of farming occurs and a retreat into marginal subsistence production.
   - Social inequities are exacerbated: marginal populations of semi-landless workers increase; while other farms respond to new market opportunities.

- As maximum carrying capacity is reached, the system becomes more vulnerable to shocks eg. natural disasters, crop failures.
- Challenge to the small farm: as world population grows (at approx. 2% p.a.) and urbanizes (by the year 2000 agricultural population will be about 50% of the world total) the farm community will have to produce much more than their own family needs.

II. Issues:

1. Is the small farm a poverty trap? Some small farm systems are rapidly degenerating (especially where soils are degrading) to a point where the desirability of sustaining their agriculture is questionable as a long-run objective.

   Issues for agricultural research in this context include:

   - Is CIAT's technology development giving sufficient consideration to impact on employment and income generation for the semi-landless?
   - Will low-input technologies geared to more effective use of scarce resources contribute to mining the land more rapidly?
   - What policy measures (in the absence of land reform) are required to introduced new resources eg. subsidized credit for fertilizers?
   - Should policy research receive more emphasis?

2. Can new systems be designed for sustainable small farms?

   Strategies for "open systems" vs "closed" (traditional) small farm systems might include:

- Introducing new cash crops (high value, labor intensive) eg. snap beans.
- Research on post-harvest processing, new market outlets for traditional crops (cf. cassava).
- Research on crop-livestock systems: milk production as a source of cash income; nutrient recycling thru livestock and use of animal manure; integrating leguminous fodder crops, tree crops for rotation and soil conservation etc. with traditional crops (such as cassava).
- Intensification of existing systems with additional inputs; improved recycling of nutrients.

Issues:

- Less emphasis on improved productivity in single commodities/more emphasis on designing new systems (including livestock)?
- More emphasis on integrated production-market development approach?
- More research on low inputs in relation to nutrient recycling, replacement of nutrients, ie. whole system interactions?
- More concern with income generation (creating capacity to introduce purchased inputs) vs. productivity alone?

3. Implications for research organization concerned with sustainability of small farms:

- Site specificity of research to design new small farm systems.
- Does this require a shift in the relative emphasis given to on-farm vs. on-station technology generation? More decentralization?

- Can CIAT develop tailor-made systems? (probably not). This may imply less emphasis on "finished" technology (ie. varieties) more emphasis on "prototype" technologies for national programs to put into location-specific systems.
- National program capacity to put together site-specific systems then becomes critical: does this imply a greater emphasis on training and networking by CIAT to create this capacity?
- Should CIAT give more emphasis to "upstream" training (Ph.D. thesis etc.), less to short courses, to improve this capacity?
- Site-specific, on-farm systems research requires immediate, sustained feedback from farmers: Should farmer evaluation receive greater emphasis on CIAT's research and training?

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Sustainability Issues in the Amazonian Tropical Rainforest

I. Introduction: Discussion of the Amazonian tropical rainforest is replete with controversy. This controversy derives both from a basic divergence in values attached to long term development of the region and from the extremely limited research history and data base which underlie much of the debate over development strategy. Theory and ideology have filled the void in data, causing polarization in positions. The first objective here is to give both an overview of sustainability issues in this debate and a flavor of the controversy that surrounds each of the issues. The second objective is to pose some questions concerning CIAT strategy in this ecosystem.

The research agenda on the Amazon is principally being set by tropical ecologists and, to a more limited extent, anthropologists. Thus, the literature reflects a tendency to a conservationist position. The developmental position in the literature is in large part a reaction to the tropical ecologists and, as is usual in a reactionary point of view, has not developed a fully coherent and comprehensive argument.

II. Sustainability problem structure:

A) The tropical rainforest encompasses a multiplicity of specific sustainablity issues; these derive from the conversion of a resilient ecosystem (the tropical rainforest) to agricultural/forestry systems, which in many cases have proven to be unsustainable with available technologies and existing input/output prices. Ecologists have provided the paradigm for understanding productivity and dynamics within these two ecosystems. Both systems are subject to significant biotic stresses and are conditioned by the low fertility status of highly leached soils. The individuals within the forest ecosystem can be highly unstable and ecosystem composition is quite dynamic. However, the overall system is highly resilient due to substantial species diversity, which allows compensation for instability in individual components. Conversion to an agricultural, pastoral, or agroforesty system radically narrows species diversity; this leads to a more marked response of the system to pertubation as the buffering capacity of diversity is lost and nutrient cycling capacity is diminished. Such system response often has a long term trend, thus leading to the concern over sustainability rather than stability.

B) The mechanism underlying this conversion is deforestation, either partial or complete. Whether conversion is reversible is open to debate. First, there is the issue of whether rainforest will be converted permanently to savanna, principally as a result of the short length of seed dormancy of rainforest species and loss of seed sources (Buschbacher, 1986; Jordan, 1982) -- see Janzen's (1986) discussion of the living dead. Second, there is the issue of the conditions under which and the time required for cleared areas to return to secondary forest, and the quality and diversity of the secondary forest compared to primary forest (Uhl, 1987; Rogers, 1986).

C) The rate of conversion must be seen as a process influenced by social and political factors determined to a significant degree outside the tropical forest ecosystem itself.

D) Sustainability issues in this conversion process occur at two levels: the macro-ecosystem level and the micro-agro-ecosystem level.

III. Sustainability issues arising at the macro-ecosystem level.

A) The debate: in the balancing of development and conservation objectives, what percentage of the tropical rainforest should or can be maintained, what is an optimum use level of this forest, and what percentage of the rainforest should be converted to agro-ecoystems?

B) The concern derives from the as yet unknown, but apparently irreversible, effects of widespread deforestation on the local, regional and global ecosystem. These macro-ecological effects are essentailly three:

1) Significant change in the hydrological cycle, leading to a marked effect on local and regional rainfall. About one-half of the precipitation is recycled via evapotranspiration in the Amazon Basin compared with a global average of 12% (Salati, et.al., 1979; Salati and Vose, 1984; and Gat, et. al., 1985).

2) Significant contribution to atmospheric carbon dioxide and global warming. Houghton, et.al. (1983) have suggested that terrestrial biota have released as much carbon to the atmosphere as the burning of fossil fuels. About 80% of the flux from the biota to the atmosphere is due to conversion of tropical forest to agricultural and ranching systems (Buschbacher, 1986). The debate vis-a-vis the Amazonian tropical forest can be followed in Brown and Lugo (1982); Fearnside (1985); and the brisk interchange in Interciencia (1986).

3) Irreversible loss of unknown and unevaluated genetic and cultural diversity. Tropical moist forests contain 40-50% of all the earth's species (Meyers, 1979); moreover, the particular species of plants and animals that inhabit tropical rainforest are not as resistant to perturbation as the system as a whole (Buschbacher, 1986). Loss of indigenous, human populations leads to the loss of the culture and knowledge to exploit this genetic diversity (Prance, 1985). For a particularly eloquent statement of the difficulties involved in preservation of this genetic diversity see Janzen (1986).

C) Interventions would seek to control the rate, scale and location of deforestation and the land use that follows deforestation. There are indirect interventions which seek to control the rate of immigration and colonization and direct interventions which seek to control land use and scale of clearing during the colonization process.

1) The immigration process into the Amazonian rainforest is only marginally driven by growth in rural population, principally that in the Sierra of Bolivia and Peru. Rather immigration is principally determined by access -- i.e. highway development -- and relative economic incentives -- i.e. potential income in colonization areas

versus either potential income in traditional rural areas or wage income in urban areas. In the 1970's in Brazil immigration to Amazonia represented only 6% of total migration during the decade (Wood and Wilson, 1984). To motivate migration relative economic incentives have been heavily influenced by government subsidies, especially in Brazil and Peru.

2) Scale of clearing is related to eventual land use, farm size and government subsidies. In Brazil, Hecht (1983) estimates that 95% of the land cleared has been sown to pasture. Large-scale, mechanized clearing was up to the early 1980's heavily subsidized. Withdrawal of subsidies has apparently resulted in significant decline in deforestation, although data are lacking to demonstrate this -- the latest LANDSAT estimate in the literature is 1980 -- and Fearnside (1985) suggests this policy change has not been fully implemented.

3) Controlling access through protected reserves (parks and American Indian reserves), controlled access to public forest, and zoning on the basis of land use capability. The debate here surrounds the ability of institutions to put land use policy into effective practice (Moran, 1984; Goodland, 1986; Fearnside, 1985). Compatibility of contiguous but alternative land use forms (in this case pasture and low impact harvest of forest) has also been called into question (Uhl and Buschbacher, 1985).

D) Policy measures, both national and international, have focused on: (1) controlling highway development or the deforestation consequences there of -- the U.S. Congress recently put pressure on IDB to suspend loan disbursement on a highway project in Acre, Brazil because environmental guidelines were not followed (EDF, 1987) -- (2) strengthening land use planning and the data and research base which underlie it; and (3) reducing subsidies which have led to speculative land markets. Since the principal restriction on deforestation of the Amazon is profitability of production activities in the region, there is general agreement that profitability of these activities should not be artificially maintained by subsidies. There is, moreover, concern surrounding what the focus of agricultural research, oriented to developing profitable production systems for this region, should be and the implications it would have for eventual land use.

IV. Sustainability issues at the micro-agro-ecosystem level.

A. The debate: given the severity of edaphic and biotic stresses in Amazonia and the high input prices relative to output prices, what should be the appropriate design of agro-ecosystems that ensures both their sustainability and a moderating effect on deforestation?

B. The concern derives from the exploitative and short-term time horizon of a major portion of land use in the Amazonian rainforest. The principal land use forms are shifting agriculture and pasture. Shifting agriculture, although maintaining the regenerative capacity of the rainforest, is only viable at low population densities and is not seen as a viable basis for economic development. Pastures are by far the largest land use, but due to a multiplicity of constraints, including lack of fertilizer use by farmers, an estimated 20 to 50% of the pasture area is degraded (Hecht, 1983).

C. Constraints conditioning sustainability of agro-ecosystems may be divided into ecological and economic factors.

1. Ecological sustainability refers to overcoming biotic and edaphic constraints by principal reliance on management of natural processes. These constraints are:

   a) Low inherent soil fertility with high rates of leaching and fixation of applied phosphorous. There are areas of higher fertility soils but low fertility status soils dominate. The nonsustainability of most agricultural and pasture systems is due to sole dependence on nutrients released in burning of the forest. To date research indicates that sustainable systems must depend, among other things, on some amount of fertilizer application (Buschbacher, 1984).

   b) Because of the level and intensity of rainfall, the erosion potential of alternative land uses at different slopes is a key determinant of sustainability. Proper soil management is key to the profitable use of fertilizer. Fearnside (1987), moreover, suggests a distinct trade off between high fertility soils and suitable topography, implying that Alfisols and Vertisols occur in more steeply sloping terrain.

c) Biotic constraints are considered to be severe. Because soil factors are the most obvious, initial constraint, the role of biotic factors on the sustainability of agro-ecosystems can be underestimated. Weeds are a severe constraint on annual crops and pastures, often exacerbated by labor constraints. Moreover, there is an interaction between low soil fertility and weed growth and, possibly, susceptibility to diseases. Tree crops are often seen as a key component of sustainable systems, with some suggestions to utilize products of economic value from indigenous trees. The disease problems attendant from intensifying production of these tree crops remain to a large extent unknown, as is the potentail for utilizing genetic resistance to reduce disease severity, especially given the difficulty of tree breeding. Introduced tree species provide some potential options.

2. Economic sustainability is key to the development of the region and refers to the ability of the system to remain profitable over time. Principle factors underlying profitability of agro-ecosystems in the Amazonian rainforest are:

a) High transport and labor costs: Development of the Amazonian rainforest will be significantly different from development of the tropical rainforest in West Africa and Southeast Asia due to the far greater distance to ports and markets and far less labor availability. Not surprizingly the key examples of economically sustainable systems are small-scale pepper and cocoa production in the Belem area (Jordan, 1986) -- this is not to lessen other characteristics of these systems which underlay their sustainability.

b) High input costs and low output prices relative to alternative agricultural areas. To date it is not clear which crops, if any, have a natural comparative advantage in the rainforest -- this is more stringent in Brazil, Ecuador and Colombia than in Bolivia and Peru. In Brazil crops (or their direct substitutes) of any significance can be produced more cheaply in other agricultural regions. Partly because of low and uncertain profit margins, the inputs, on which sustainable production is often dependent, are not applied by farmers.

c) Production and transport subsidies, especially in Peru and Brazil, have been utilized to artificially support profit margins. As the withdrawal of subsidies for pasture establishment in Brazil has shown, economic sustainability should not be dependent on subsidies.

d) High management requirements are inherent in systems where sustainability depends on high input and labor use. Systems which rely on self-sustaining, natural processes probably require less management, at least after the establishment phase.

D. The basis for eventual intervention is research leading to the development of ecologically and economically sustainable agroecosystems. The sustainability debate centers around what the appropriate design of those systems should be, including the choice of crop or production system. The most important design criteria appearing in the literature are as follows:

1) Ecosystem mimicry. Design of agro-ecosystems would incorporate diversity, successional, and nutrient cycling characteristics of the forest (Hart, 1980; Altieri, et.al., 1983; Ewel, 1986). However, as Ewel (1986) notes, "The benefit of forest-like agroecosystems (to date) is low risk; the limitation is low yield", although the later is compensated for by higher value of the product.

2) Scale of the production system. Jordan (1986) argues that because of complexity inherent in managing sustainable systems in the rainforest, the necessity of input use, the general scarcity of labor, and the relatively low management skills, small-scale systems are more sustainable (and result in lower rates of deforestation). Economists could argue (but have not) that the more land extensive nature of pasture and some plantation systems reflects the virtually unlimited supply of land and that such resource use is rational, given the important proviso that there are no social costs or externalities. However, since most current land-extensive pasture systems depend only on nutrient release from burning (Buschbacher, 1986) -- and these is often adverse effects on forest regeneration --, the systems have not proven to be sustainable. The scale issue remains unresolved.

3) Continuity of cultivation. The fixing of property rights usually entails the search for ecological and economic sustainability within a framework of continuous cultivation, (which does not rule out ley and green manures). For annual crops, most published research on such systems has been generated at Yurimaguas, Peru and the research group there suggests that such systems are viable (Nicholaides, et.al., 1983 and 1985). Fearnside (1987) critiques these claims. As usual in many of these debates, what is lacking is a sound economic evaluation and extensive, well designed on-farm testing. The issue is still open.

4) Efficient nutrient use and cycling. Adequate plant nutrition is a principal constraint to sustainable systems, complicated by high fertilizer costs and lack of effective soil management practices. The literature is surprisingly limited and is dominated by tropical ecologists, who have tended to focus on nutrient cycling in forests and nutrient dynamics in pasture systems. Phosphorous is a key constraint to pasture performance and, without mineral supplementation, to cattle performance (Buschbacher, 1987; Serrao, et. al., 1978). There is room for

more research on plant nutrition and nutrient cycling. Given constraints on access to fertilizer, its high cost, and farmers' capital constraints, basing agroecosystems on efficient nutrient cycling -- which does not imply no fertilizer -- appears basic to the development of sustainable system.

5) Minimizing disease and weed incidence, if the history of rubber is any example, is essential for sustainable systems. Forecasting what pathogen constraints and thier epidemiology will be is especially problematic in this untested ecosystem. Species diversity, either spatial, temporal, or both, is seen as basic to ensuring agroecosystem sustainability.

6) Appropriate "economic" characteristics of cash "crops". These would include high value to transport costs, low labor intensity, low purchased input requirement, stable markets and low market risk. The issue is whether there are production activities in which the Amazonian rainforest has a comparative advantage. It could be argued, on the other hand, that rapidly expanding, indigenous, urban markets in the Amazon will become the principal markets.

V. There is a basic dilemma in how sustainability issues at the micro-agro-ecosystem level are made compatible with those at the macro-ecological level, especially the appropriate use of limited research resources. Buschbacher (1986) puts the issue this way: "Perhaps the most valid argument against Amazon deforestation is that constraints of transport and soil fertility make it unlikely that conversion to pasture (or other production activities) can be economically viable. Limited resources would be more wisely invested in other areas more amenable to development." There are then three different levels of decision-making as regards allocation of research funds to the Amazonian rainforest.

A) Given the important proviso that governments have a non-interventionist policy, particularly lack of highway development and of subsidy support for land clearing and transport, then doing nothing may be a potentially viable strategy. The issue here turns on what is pulling migrants to the rainforest and the underlying economic basis of colonization.

B) If the decision is made that a research investment is justified, the question arises of how much of the limited agricultural research budget should be directed to the Amazon compared to other research areas, especially in relation to relative cost of producing viable technologies and relative potential for impact.

C) At a third level in the research design process, the research institution should have a forecast of whether the development of profitable technologies will reduce or enhance the rate of deforestatation (see Fearnside, 1987 versus Nicholaides, et.al., 1985). Technology design, and the design of supporting programs or policies, should be made compatible with overall land use goals.

D) These issues represent the first level of decision-making for agricultural research institutes involving themselves in the Amazon. Unfortunately, because of the lack of data and understanding of the underlying processes, these all remain judgement calls.

VI. Implications for CIAT of sustainability research on the Amazonian tropical forest.

A) The Amazonian tropical rainforest is not explicitly incorporated in CIAT's objective statement. It could be argued that CIAT's geographical focus on the Latin American tropics would include it. It could also be argued that CIAT's exclusive focus on commodities would rule out a comprehensive research focus on sustainability issues in this ecosystem. Thus, can sustainability issues on the Amazonian rainforest, or a subset of those issues, be effectively incorporated into the four commodity research programs at CIAT? Some issues inherent in this question are:

1) Rice (Barrow, 1985), cassava (Smith, 1978), and tropical pastures (Toledo and Serrao, 1982) are existing and potentially important

production activities in this ecosystem. Is the tropical rainforest a high priority for these commodity programs? What percentage of resources should be directed toward this ecosystem in relation to other demands on the programs?

2) If all three programs undertake research in this ecosystem, is there scope for integration of activities and/or research areas that overlap all programs?

3) Is it clear how the necessarily limited CIAT research effort fits into the overall range of research activities in the Amazon rainforest? Is it clear what sustainability issues are being addressed by the CIAT effort and whether these are well integrated with other efforts?

4) In the end by implicitly accepting that rice, cassava, and pastures will have a dominant role in this ecosystem, is not CIAT prejudging a range of anterior issues involved in the design of sustainable production systems in this region? How can CIAT currently judge the extent to which these crops can contribute to the design of sustainable agricultural systems in the region?

B) The TAC recommended that IARC's with commodity mandates review "sustainability concerns (which) may make it desirable, if not essential, for some centers to give increased attention to research on problems of resource management." TAC further implies that this should come at the expense of "crop productivity research per se." Given this recommendation, should CIAT consider a major research thrust in the Amazonian tropical rainforest, but with a more holistic perspective and a broader mandate in which to work? Some issues inherent in this question are:

1) Would CIAT have an institutional comparative advantage in working on agricultural technologies for the Amazon rainforest? It is clear that if the CGIAR would want to involve itself in this area, it would have to be CIAT or (depending on its future status) ICRAF.

2) Is the tropical rainforest, as a "resource management" research area, of highest priority? How does it compare to, for example, soil erosion in the Andean region?

3) What committment of resources would this research focus require to produce a sustainable production impact? How would the strategy be developed? Any potential impact would probably be concentrated in Brazil and Peru. Does such a narrow country basis merit CIAT attention?

4) Does such a research focus necessarily move CIAT into more "basic" research on underlying determinants of system performance and away from applied research for technology development?

C) How does CIAT address the controversy that necessary underlies research in this ecosystem? CIAT is already significantly involved in the Amazonian tropical rainforest, and recent pressure by the U.S. Congress and U.S. conservation groups on both the World Bank and the IDB suggest that the appropriateness of any intervention by international institutions in Amazonia will at some point be heavily scrutinized. It should also be recognized that CIAT's currrent focus on pastures is without a doubt the most controversial of any possible intervention, as can be seen in this comment by the World Bank's staff ecologist in the Office of Environmental and Scientific Affairs, "The long-predicted inappropriateness of deforestation for cattle ranching on infertile soils in high temperature, high rainfall areas of low technology and management has now been carefully documented .... Even the pasture proponents are muted or rely on fertilizer subsidies or management levels yet to be commonly achieved throughout Amazonia" (Goodland, 1985). CIAT can and should address the controversy but only by being very specific in terms of its objectives, its strategy, and its forecast of impact on macro and micro sustainability issues.

John K. Lynam January, 1988

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# SOIL EROSION

## Introduction

Accelerated soil erosion results in the loss of the most basic agricultural production resource. In addition, less water is retained on the land, spring and stream flows are more erratic, flooding is more frequent and silting of streambeds and reservoirs is accelerated.

## Factors determining erosion potential

The potential for soil erosion is determined by a number of factors, some of which are susceptible to change through management, others are not. The widely used "universal soil loss equation" proposed by Wischmeier and Smith (1961) attempts to predict soil loss as a function of a number of factors:

$$A = RKLSCP$$

where:

A = Soil loss

R = Rainfall erosivity function

K = Soil erodibility function

L = Length of slope function

S = Steepness of slope function

C = Crop management function

P = Conservation practises function

Some of the functions are quite complex and often difficult to estimate in the field. The equation has, however, proven to be very valuable conceptually and there has been much progress in quantifying all the functions during the last thirty years. Unfortunately, the understanding of soil erosion processes has not been translated into effective soil conservation programs in most developing countries. There are outstanding examples of indigenous soil and water conservation systems, some of which continue to function well in traditional agricultural areas while others are breaking down under increased pressure. In general, both the current situation and outlook for the future for soils in high risk areas of the developing world are bleak.

**The role of management**

Soil characteristics which are favorably influenced by good management are fertility, organic matter content and structure. Poor management leads to deterioration of all three characters and increased erosion potential. Soil texture, mineralogy and the general topography of the land all influence erosion potential but cannot be readily altered. Effective slope length, and even slope, can be reduced by conservation practises.

Climatic factors such as total rainfall and intensity and seasonality of both rain and wind are beyond control but their effects can be somewhat attenuated by practises such as supplemental irrigation and wind breaks.

The nature of the vegetation that covers the soil from season to season and year to year is a direct consequence of management decisions. The choice of crops and their combinations and sequences will determine canopy cover, residue production, surface cover and the binding and channeling effects of roots at the surface, in the plow layer and in the subsoil.

The type, depth and frequency of tillage will determine residue management and greatly influence soil porosity, surface sealing and crusting and infiltration rates. The quantity and quality of residues and their management will directly affect the development of soil fauna and flora and their effect on soil structure and porosity. In addition to these practises, special conservation techniques such as terraces, contouring, protected waterways, strip barriers and windbreaks are sometimes effective in mitigating the effects of adverse climatic factors on highly erodible soils.

**Where is the risk highest?**

All of CIAT's programs work in environments where several of the soil loss determining factors are adverse. In some instances, all six factors approach "worst case" conditions.

Geographically, the risk of erosion is highest on steep mountain and hill slopes, in the high jungle, in piedmont regions and in rolling to broken jungle and savanna landscapes. Climatic factors which increase erosion hazard are intense rainfall and strong winds during seasons when the soil is poorly protected.

Soils which are weakly structured due to low organic matter content, sandy texture, 1:1 clay mineralogy or other causes are especially erodible. Soils with inherently low infiltration rates due to platey structure, or excessive clay content

(2:1 "swelling" clay minerals) are also at high risk. Low fertility can also contribute to accelerated erosion if plant growth is slow and/or sparse during or after cropping.

Farming systems which are based on annual, short cycle crops requiring intensive land preparation for each cycle are at greatest risk. This is especially true if monocropping is practised and if the principal crops provide poor soil protection and produce or leave little in the way of residues to cover the surface.

Small farmers are frequently found on the most marginal land in a given region; land that is often highly susceptible to erosion. Because of lack of resources, they are usually forced to plan within a very short time-frame and cannot afford to allot much, if any, of their resources to a long-term conservation strategy. They almost never have access to technical assistance nor credit for conservation practises, all of which leads to high erosion risk.

The following is a list of the ecosystems judged to be most susceptible to erosion and the CIAT programs whose activities might be expected to have the greatest effect in each area:

| **Ecosystem** | **Program** |
|---|---|
| Mountain slopes: | Beans, Cassava |
| High jungle: | Cassava, Pastures |
| Piedmont hills and rolling plains | Rice, Cassava, Pastures |
| Rolling to broken savanna and jungle landscapes: | Pastures, Rice, Cassava |

## CIAT activities and erosion potential

The development of improved germplasm and technology often leads to higher or more stable yields and lower costs of production. This makes a given crop more attractive than other crops not similarly favored and influences farmer decisions. The new germplasm may decrease erosion potential on the land where it is grown by improving plant vigor, early canopy cover, and the production of more residues. It might also increase farmer income and stability and thus reduce the tendency for expansion onto more marginal land. On the other hand, the new varieties might prove so profitable that farmers would increase their total planted area, displacing other crops or expanding onto more marginal land and increasing erosion potential.

CIAT has the potential to directly influence the priorities and policies of national institutions in some countries. Almost all the institutions with which the center collaborates are influenced indirectly through research and development programs, training, communications, workshops and many other avenues. Changing policies affect farmer decisions through production incentives, seed supplies or other means, and may result in altered cropping systems which in turn may affect erosion potential, either positively or negatively.

## Questions:

1. Where and how are CIAT activities most likely to affect erosion potential:,
   - a) By contributing to solutions
   - b) By exacerbating the problem

2. Are erosion problems so site specific that they should be left to the national institutions?

3. Are solutions to soil erosion problems available, waiting to be applied directly or adapted to specific situations?

4. How could CIAT's commodity programs collaborate more closely to take advantage of the potential benefits of crop rotations, especially ley farming systems, in the area of erosion control?

5. Is there need for an entirely new initiative in the form of a serapate unit in the area of cropping systems and/or conservation practices to address the problem?

6. Are other international or bilateral programs effectively addressing the problem of soil erosion in CIAT's commodity/geographic areas?

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**DRAFT**

# SUSTAINABLE AGRICULTURAL PRODUCTION:

# IMPLICATIONS FOR

# INTERNATIONAL AGRICULTURAL RESEARCH

Draft Report of TAC Continuing Sub-Committee II

October 1987

# SUMMARY

From its inception, a major goal of the CGIAR 1/ has been to increase food production in developing countries. Much of the work it supports has also been concerned with sustaining production for the needs of future generations.

In its study of CGIAR prorities and future strategies, TAC recommended that the word "sustainable" be included in the System's goal statement and that greater emphasis be placed on sustainable production systems in future work of the Centers. In this paper, TAC reviews the circumstances threatening sustainability, analyzes areas where international research could contribute more effectively to the development of sustainable agricultural production, and makes recommendations for the future work of the Centers.

## TAC's Concept of Sustainability

A dictionary definition of sustainability refers to "keeping an effort going continuously, the ability to last out and keep from falling". Such a definition would suggest that agricultural systems would be sustainable if production could be maintained at current levels. This would be a static concept of sustainability. But sustainability should be treated as a dynamic concept, allowing for the changing needs of a steadily increasing global population. In the static sense, many traditional agricultural production systems were sustainable for centuries in terms of their ability to maintain a continuing, stable level of production. However, the needs and increasing aspirations of expanding numbers of people have forced changes in production practices that have imposed excessive demands on the natural resource base.

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1/ A List of Acronyms is given at the front of this document.

Within this context, sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the natural resource base and avoiding environmental degradation.

## Trends in Agricultural Production

Characterized in this way, sustainability should be considered in the light of past and current trends in agricultural production.

Aggregate statistics look very positive in terms of food production in developing countries in the 30-year period from 1950 to 1980. During this period, food production in the Third World experienced a compound rate of growth of 3% annually. Per capita food production in the developing world also improved, with a compound rate of growth of 0.6%, even though populations grew rapidly during the same period.

Despite this remarkable progress in expanding food production, the needs for further improvement continue to mount. Food deficits remain critical in Africa, where per capita food production has dropped by almost 20% in the last quarter-century. Furthermore, despite the overall increase in per capita food production in the developing world, it is estimated that half the population cannot afford a diet that meets the minimum energy needs for a healthy, active life.

## Circumstances that Limit the Achievement of Sustainability

### Difficulties in Maintaining Progress in Food Production

There is much evidence to suggest that in the developing countries it will be difficult, but by no means impossible, to maintain into the forseeable future the rate of progress in food production realized over the past 20-30 years. For example, it is doubtful if those regions that have benefitted from the green revolution in rice and wheat production can continue to enjoy the same rates of gain in productivity that have occurred in recent decades. Furthermore, there will be great difficulties in extending the green revolution in rice and wheat to the other half of rice and wheat producers in the developing world whom it has not yet reached.

But aside from the difficulty in sustaining the rates of gain in food production through the green revolution, there are many circumstances that will make the realization of sustainable production systems extremely difficult, unless remedies can be found and implemented.

## Population Growth

On a global basis, agriculture must produce enough to feed some 80-100 million additional people each year. The enormity of this problem is highlighted by the fact that about 90% of this increase in population is occurring in the developing world.

Such growth in population poses one of the greatest threats to the achievement of sustainable production systems. Expansion in the numbers of people increases the demand for more cropland while, simultaneously, expanding the need to take land out of production to accommodate other requirements. Furthermore, expanded food production in response to rising demand increases the pressures on those natural resources that are vital to sustain production - often with serious consequences for the environment.

## Limited Opportunities for Expanding Cultivated Areas

There will be limited opportunities to expand the global base of productive agricultural land. New areas brought into cultivation will do little more than compensate for the loss of agricultural land diverted to other uses or otherwise lost through various processes of degradation. It is apparent, therefore, that growing demands for agricultural products must be met primarily by intensification of production on existing arable land, rather than by bringing new areas into cultivation.

## Unfavourable Political, Economic and Policy Environments

Political instability in some developing countries has been a major deterrant to sustained agricultural development, which has been further hampered by the low priority accorded to agriculture by many national and local governments. Such low priority is reflected in many ways, including a low level of investment in the development of the agricultural sector as well as in policies for trade, taxation and pricing. Often, the terms of trade are skewed against the agricultural sector, leading to artificially low internal prices for agricultural commodities, which favour the urban consumer at the expense of the farmer. In many countries, agriculture is not provided with the financial and institutional support its central role in the economy warrants. Moreover, such policies act as deterrants to the achievement of sustainable agricultural production because they do not provide the necessary incentives to producers to invest in sound farming practices that minimize degradation of the environment.

In many developing countries, weak infrastructure is a major constraint to the delivery of inputs and transport of farm commodities to market. Extending infrastructure helps to remove these constraints and allows further intensification of production in favourable areas, which helps to reduce the pressure for increased production in the more fragile environments.

In many circumstances, the achievement of sustainability will require the use of purchased inputs such as seed, fertilizers, pesticides, implements and machinery. In addition to the limitations to their availability imposed by poor infrastructure, their availability is also limited by high prices and the lack of credit to purchase them.

The development of strong, viable and effective agricultural research, extension and education programs is vital to the achievement of sustainability. Despite the high financial returns to investment in such programs revealed by many studies, there is widespread evidence that they are underfunded in most developing countries.

Systems of land tenure may also impose limitations on agricultural development and the achievement of sustainability, by acting as disincentives to producers, for example, to conserve natural resources and invest in the future productivity of the land.

## Physical and Biological Factors Affecting Sustainability

### Physical Factors

Soils. No single resource is more important to the achievement of a sustainable agriculture than the soil which contains nutrients and stores the water for plant growth. Deficiencies or excesses of either can seriously limit productivity. Their availability in appropriate amounts is heavily dependent on the manner in which the soil is managed.

Moreover, in many parts of the world, soil erosion has increased to the point where losses exceed the formation of new soils through weathering. When this occurs, the soil is, in effect, being mined, converting renewable resources to non-renewable ones. When topsoil is lost through erosion, there is a loss of fertility and a deterioration of physical properties, resulting in a decline in productivity.

Population pressures are contributing to other difficulties in maintaining soil productivity. As fuelwood supplies are diminished, expanding populations in many areas have become increasingly dependent upon crop residues and animal manures for fuel, thereby reducing their use in replenishing nutrients and organic matter.

Water. Agriculture is the principal user of global water supplies. From historic times, irrigation has been used to help farmers to secure a reliable and timely supply of water for their crops. During the 1950s and 1960s, irrigated areas expanded at the rate of about 4% annually. By the early 1980s, the rate of growth had declined to less than 1%.

Non-sustainable use of water is occurring in a number of agricultural areas throughout the world, involving both the use of fossil water as well as the overdrafting of rechargeable aquifers.

Irrigation water is often used inefficiently, with much more water transported and applied than crops require. Furthermore, poor irrigation practices result in severe problems of land degradation through water-logging, salinization or both.

For those vast areas in developing countries that depend on rainfall for their agriculture, efficiency in its use is just as important as for irrigation water. Inappropriate soil and water management under rainfed agriculture is one of the primary causes of land degradation.

Toxic Chemicals. Human activities are responsible for releasing chemicals into the environment that may have serious deleterious effects on plants and animals. For example, certain industrial processes, along with the combustion of fossil fuels result in the release of large quantities of sulphur and nitrogen oxides into the atmosphere. These gases combine with moisture and come down as acid-contaminated rainfall, which has the potential to damage both terrestrial and aquatic organisms. Furthermore, acid rain may contribute to the acidification of soils which, in turn, may adversely affect productivity.

Industrial activities involving high-temperature processes have also resulted in pollution of the atmosphere through the release of a number of metals, which are potentially toxic to plant and animal life, if allowed to accumulate in soils or water. In addition, chemicals with beneficial uses, such as fertilizers and pesticides, can become harmful if used inappropriately. The ability to benefit fully from such chemicals in the future may well depend on refinements in their use.

Climatic Change. There is considerable evidence pointing to a significant warming trend in world climate. Such a trend is a result of a build-up of carbon dioxide and other gases in the atmosphere, which could have significant, longer-term effects on agricultural production systems and their sustainability.

For example, coastal lowlands could suffer increased risk of flooding caused by a greater melt of polar land ice. Possible effects of the warming trend on precipitation are more speculative, although various models suggest that some regions could become more arid and others more humid.

Biological Factors

If the food needs of rapidly increasing populations are to be met, both yields per unit area and per unit time must be substantially increased. Such intensified production favours the build-up of weeds, diseases, arthropods, rodents and birds (collectively referred to as "pests") which, unless adequately controlled, seriously limit productivity. Although there is wide variation, it is estimated that pests contribute to field losses of some 35% of the potential production of major food crops, with the greatest losses occurring in the developing countries.

The long-term control of pests is also threatened by break-downs in the effectiveness of pesticides and host-plant resistance through mutation of the pests. The research required to maintain the levels of control already achieved has an important part to play in the achievement of sustainability.

The sustainability of animal production is partly dependent on finding improved methods of controlling diseases and parasites, which cause high mortality among livestock in developing countries and seriously reduce productivity.

For the continued genetic improvement of both plants and animals, the conservation of genetic resources is of paramount importance and should continue to receive urgent attention from national governments and relevant international organizations.

## Contributions by International Institutes and Organizations to the Goal of Sustainability

TAC requested all the IARCs, as well as a wide range of other international organizations, to provide information on their current activities related to sustainability. They were also asked for their views on the needs for further research to assist in achieving sustainable agricultural production.

The information provided in response to these requests is summarized in Annex 1 and briefly reviewed in Chapters 4 and 5 of this paper.

## Recommended Strategies for Progress Towards Sustainability

If sustainability in agricultural production is to become a reality, not only must the circumstances that threaten it be alleviated, but there must also be major efforts to increase productivity to meet growing needs. TAC views the challenge of finding timely and workable solutions to these problems as one which should receive the highest priority from all organizations that can make a contribution.

Many of the circumstances that limit the achievement of sustainability, however, cannot be solved by the CGIAR or through agricultural research alone. It is national governments and their development services that must bear the brunt of the problems and on whose commitment progress in achieving sustainability depends. Nonetheless, continuing research is crucial for success and international research institutions, as well as national agricultural research systems, must continually examine their programs to give greater emphasis and visibility to those aspects that relate to sustainability.

Although the resouces of the CGIAR are small relative to total global expenditure on agricultural research by the public sector, the Centers can have a disproportionate impact through their ability to influence the nature of research at other institutions. Furthermore, donors and other components of the CGIAR System can be helpful in focusing attention on sustainability, and encouraging governments and relevant institutions to accord it high priority.

A great deal of the work being undertaken by the Centers already relates, to a greater or lesser extent, to problems affecting sustainability. The question that arises, therefore, is not so much whether the Centers are working to make agriculture more sustainable, but whether they should be doing more, and whether there should be a different emphasis in the work.

## Research with a Sustainability Perspective

TAC does not view research related to sustainability as a separate or discrete activity. Rather, concern for sustainability should be reflected in the way in which the research is approached. TAC therefore recommends that research at the Centers designed to generate new agricultural technology should be planned and conducted with a sustainability perspective. TAC further suggests that in formulating or revising their strategic plans, Centers should include proposals for maintaining a sustainability perspective throughout their total program.

## Short-term versus Long-term Objectives

If the goal of sustainable agriculture is to meet the changing needs of people, research must clearly cater for both short-term and long-term needs. Nevertheless, a guiding principle for Centers must be that stability of the environment should never be consciously sacrificed for short-term gains. The aim should be to devise technologies that can meet short-term requirements while, at the same time, maintaining or enhancing the ability to meet long-term needs.

## Low-input Agriculture

TAC considers that research on low-input agriculture should feature more strongly in Center programs. The aim should be to optimize productivity from the use of low levels of purchased inputs, consistent with the requirements of sustainability. The ultimate aim would be to promote a gradual evolution towards the use of higher levels of inputs, where needed, and the development of technologies that reduce the risk of uneconomic returns.

Technologies geared towards the more effective use of scarce resources can aggravate the problems of soil mining, unless nutrients are recycled as manure or plant residues, or replenished through the use of fertilizer. There are large differences, however, in the demands for nutrients made by different crops and different production systems. Cassava production systems, for example, are sustainable with very low inputs.

Centers should review the emphasis given to low-input farming in their research programs, and increase it where appropriate. They should also review their approaches to research on low-input farming to ensure that the sustainability perspective is adequately taken into account.

**High-input Agriculture**

Without the existence of high-input technologies, it would be impossible to meet the food demands of the increasing world population unless more, but less suitable, land were brought into cultivation, further raping the surface of the earth and destroying natural ecosystems in the process.

TAC considers that, under appropriate conditions, the use of high levels of industrial inputs can make important contributions to sustainability and recommends that high-input technologies be included in research programs of the CGIAR Centers. TAC suggests, however, a selective approach to research related to sustainability in these production systems that restricts in-depth investigation to problems that are especially relevant to tropical and sub-tropical environments.

Sustainability and Equity

TAC reaffirms its earlier recommendation that the Centers give greater emphasis to the development of technologies that are especially applicable in less-endowed regions. In addition, TAC stresses that assessment of these technologies with respect to sustainability requires a thorough analysis of evolving agricultural policies in the domains of their application.

**Improved Production Systems, Including Agroforestry**

There are dangers both in disregarding the principles of traditional production systems and in assuming that, because they are appropriate in some circumstances, they will remain appropriate in others.

TAC encourages Centers to continue to investigate aspects of more intensive production systems based on sound ecological principles and the conservation of resources. Whenever appropriate, this work should include aspects of agroforestry.

Balance in Research: Productivity versus Resource Management

Although productivity research includes many aspects of resource management, the strengths of the various components of the multidisciplinary approach must be kept under review to ensure an appropriate balance. Plant breeding, for example, can continue to contribute much to sustainability, but must not dominate Center programs to the extent that other approaches are neglected.

TAC recommends that Centers with commodity mandates review carefully the relative emphasis being given to genetic improvement in comparison with other aspects of productivity research. Sustainability concerns may make it desirable, if not essential, for some Centers to give increased attention to research on problems of resource management.

Techniques in Biotechnology

Centers must constantly assess, in relation to other needs and opportunities, the potential contribution to their work of new techniques emerging from advances in the biological sciences.

TAC considers that Centers involved in productivity research should have the capability to monitor advances in biotechnology and, when appropriate, develop the in-house capacity to use techniques that would assist their programs in a cost-effective manner.

Policy Research

Policy research has a particularly valuable role to play in the CGIAR System through its intimate interaction with technology research and the changing comparative advantage that this research provides.

In its study of priorities and future strategies, TAC recommended a significant increase in policy research. TAC reaffirms this recommendation and urges that a concerted effort be made to provide additional funding for this purpose.

**Relations with National Agricultural Research Systems**

Centers could be very effective in encouraging national agricultural research systems to give greater attention and priority to considerations of sustainability, as well as in helping to strengthen their capacity to do so.

TAC recommends that Centers give high priority to strengthening the capacity of national agricultural research systems to incorporate a sustainability perspective into their research approach.

**Training**

TAC further recommends that Centers give high priority to the incorporation of a sustainability perspective in training programs, making adjustments, where necessary to meet, more effectively, the needs of national agricultural research systems in this respect.

**Collaboration with Institutions Outside the CGIAR System**

TAC recommends that Centers continue to explore the potential for collaboration with other research institutions, including those in the private sector, particularly with a view to strengthening their research related to sustainability.

**Research Needs and Resource Implications**

While the Centers and the national agricultural research systems already make important contributions to the solution of problems related to sustainability, the total current effort is unlikely to be adequate.

In view of the serious problems limiting the achievement of sutainability, and the urgency for additional research to assist in their solution, TAC recommends a substantial increase in Center funding as a significant international contribution to meeting this need.

TAC considers that, because much of the required additional work relates to protection of the environment and the conservation of natural resources, it might well be possible to widen the avenues for donor support for this vital new thrust, compared with support for productivity research *per se*.

While many of the circumstances that limit sustainability cannot be alleviated through work supported by the CGIAR, members of the Group can bring their influence to bear in creating a greater sense of urgency amongst all concerned. TAC further suggests that the issue of agricultural sustainability has major implications for the further development of the Third World and, indeed, for future global security.

TAC considers that the international donor community, as well as the governments of developing countries, have crucial roles to play in emphasizing the need to consider sustainability in allocating future resources and orientating future thrusts.

## Conclusion

TAC has characterized sustainability in terms of the dynamics of population growth and resource conservation. The common challenge facing all concerned is to find ways of removing the impediments to sustainable agricultural production, whether the causes are technical, social, institutional, political, or some combination of all four.

A significant part of this challenge rests with the International Agricultural Research Centers. Accepting it offers them opportunities for unprecedented contributions to the global community, as they help to find solutions to serious problems that significantly affect the future of mankind.