PART I

Sustainability - issues and approaches:

i) Goals and Concepts

We have based this paper on the assumption that the goal of a sustainable agriculture is to maintain a growth rate of agricultural production compatible with the needs of an expanding world population for food and raw materials, while minimizing environmental degradation or other destabilizing influences, whether political, socioeconomic, or technological.

Clearly sustainability is a dynamic not a static concept: it is not just conservation, and in this light a more succinct description might be 'Sustainability is the successful management of resources for agriculture to satisfy changing human needs'. This definition avoids imposing judgmental pre-conditions as to how this objective should be achieved; although the word 'successful' at least implies that undesirable ecological or social side-effects would be minimized. We have used "resources for agriculture' rather than 'agricultural resources', since some of those resources will have to come from outside the agricultural sector. We believe that 'management' covers decisions as to policy for the allocation as well as the use of resources, and that it applies to all levels from the national planning secretaries to the individual producer. 'Change' suggests a continuing evolution from the future but avoids specifying any particular time horizons. We have used 'satisfy' rather than 'meet', 'supply', or 'cope with', since in the last resort, success will depend mainly on people's cooperation to

achieve the satisfaction of felt needs rather than the arbitrary imposition of top-down decisions. This is reinforced by the deliberate choice of 'human' rather than 'global' in our definition: global is too impersonal and probably too theoretical a concept. Finally, we have avoided attaching the qualifying 'basic' to human needs, since different societies will have different views as to what this implies. We hope that this concept of sustainability is in line with the TAC Sub-Committee's definition in response to our query concerning its meaning in the outline issues paper sent to Rome by IFPRI on 30 January.

A narrower, but still valid concept of sustainability, relates to maintaining the viability of institutions, programmes or projects established to implement policies aimed at improving resource management for agricultural development. Instability and lack of continuity of support to development programmes by donors and by national governments leads to loss of sustainability. This view is not in conflict with the wider definition indicated above; we see it as part of the problem of attaining the larger goal.

That the achievement of this goal will prove a task of formidable magnitude cannot be denied. During the next 50 years world population will almost double, reaching above 9 1/2 billion by the year 2030 according to the UN Medium Projection. Over approximately the same period an increasingly firm body of scientific evidence suggests that levels of CO_2 and other gases of anthropogenic origin in the atmosphere will almost double, leading to a progressive climatic warming. While the effects of this on agricultural production are not expected to be entirely

unfavorable; there are important areas of uncertainty, especially concerning precipitation and the effects on sea level oceanic currents, and circulation in the upper atmosphere.

Even if world climate was to remain constant in its present relatively benign state; an assumption adopted by the majority of global studies (At 2000, Global 2000, Limits to Growth, etc.), those studies are generally much less optimistic on prospects for the first quarter of the 21st Century, than for the last quarter of the present century. They tend to predict increasing food shortages and severe pressures on natural resources (especially in the densely populated regions of Asia), energy crises, sharply rising prices, and consequent widespread distress and political unrest.

Admittedly this scenario looks unlikely in the light of the current situation, with falling food and energy prices, and relative success in food production in many developing countries outside Africa. However, even if some of the statistics currently cited concerning atmospheric and oceanic pollution in industrial countries, and destruction of timber, pasture, and soil in developing countries strain credibility, the signs of increasing human pressures on the global environment are clear, and should not be underestimated.

Finally, many countries have not achieved an agricultural growth rate commensurate with population and income growth during the last 20 years, and have to catch up. Thus their future growth has to be exponential rather than linear.

All of these trends imply that firm, far-sighted, and innovative policies will be required if agriculture and indeed

human existence is to be sustained at an acceptable level. For most developing countries this implies faster economic growth with greater equity than is currently the case, a difficult political goal.

An issue to which we feel the TAC will need to devote careful thought is the time horizon over which the CGIAR has to devise policies to help developing countries achieve goals of sustainability. The success of some of those polices may depend on measures adopted by industrialized countries on some larger aspects of global environmental management as well as enlightened economic policies on their part. Action related to the shorter-term problems of sustainability is likely to be easier to plan and implement and may yield quicker results. However, it is risky to adopt short-term policies which do not take account of, or may compromise, longer-term possibilities affecting the future of sustainability, even though the degrees of certitude, and thus the likelihood of strong political action to cope with uncertain hazards, diminishes with time.

We have therefore focused primarily on policies and actions likely to be implemented to cope with sustainability issues arising between now and the end of this century, while maintaining a fifty-year horizon concerning certain important issues as means of suggesting time-phased contingency plans. Fifty years may seem a long planning horizon, but it should not be forgotten that the CGIAR has already been in existence for seventeen years, and some of its constituent institutes have existed in one form or another for over 20 years. FAO is now in its 43rd year. Although the changes and challenges that have had

to be faced during that period are great; it is virtually certain that much greater ones lie ahead. Effective policies will have to be devised and implemented both in the short and longer term to cope with these changing scenarios if a sustainable agriculture is to be feasible.

ii) Policies to promote sustainability - some general considerations:

The development of policies which promote or encourage sustainability, especially if they do not involve coercion, is likely to be difficult and complex. One reason for this is that while sustainability is a global problem the sources of environmental deterioration are usually the result of actions taken locally within individual countries, sometimes in remote areas, and often by private initiative. Even when the action seems logical and beneficial to an individual, it may damage the interests of other people in that country without them being able to prevent it or recover the cost.

Another side of the same coin is where the source of a pollution problem is in one country, but the effects are felt mainly in others. Acid rain caused by industry; effects of deforestation or overgrazing of watersheds on silting of dams, downstream flooding, or even on climate, are examples. In such cases corrective action must be initiated by the country where the source of the problem lies; but while this may well prove costly to that country, the main benefits may accrue to others.

Thus the evaluation of the costs and effects of offsetting such externalities should be an integral consideration of policies aimed at achieving sustainability. Unfortunately this

is often not the case, and admittedly there are considerable methodological problems of assessment.

A second difficulty is caused by interactions among components of sustainability. If extension or seed production services are weak; market or input supply infrastructure is inadequate; or the price ratios unfavorable, a technological 'package' may not be adopted (or adoptable) even if technically sound. This is an important reason for the gaps between farm and experiment station yields.

The attainment of sustainability thus depends on many factors which are out of the hands of the primary producers, yet increase uncertainty and constrain their allocative efficiency. This puts a premium on sound government, and effective and appropriate institutional mechanisms, in touch with the needs and aspirations of their clients.

The appropriate policies also vary with space and time. Many issues related to sustainability are context-specific, and will require specific policies and institutions for their resolution. Some actions or policies designed to promote sustainability can be planned and put into effect quickly; others can take decades, for example reclamation of some forms of environmental degradation. Corrective action may not be possible, even at high cost, after a certain point has been reached. Loss of soil on steep slopes, or desertification, are examples: genetic erosion may be equally irreversible; once a species is extinct it is gone forever. Policies related to natural resource sustainability often require longer for their successful implementation than those applied to technology or

economic measures; and may have to be applied over wide areas if they are to be effective. Investments linked to long-term policies must sustained over the long-term or the measures will fail, but provisions should be built-in to ensure that they eventually become self-sustaining.

Technological measures, infrastructural development, and institutional innovations, may require a shorter time-scale for their implementation; although the attainment of an efficient and durable institutional structure has proved a long-drawn out evolutionary process of trial and error in many countries.

Measures which can be instituted most rapidly are those of a political, financial, or managerial nature. Their efficacy, however, depends on a reasonable measure of governmental and institutional stability. As will be discussed later, this has not always been proven easy to achieve; thus the benefits of policy changes have often been ephemeral.

These complexities suggest the need to develop a typology of the various facets of the sustainability problem, even though this may not be easy to construct. This should take into account:

1. The main resources on which achievement of a sustainable agriculture depends.
2. Their inter-dependence and interactions.
3. The degree to which they are amenable to manipulation through appropriate short and longer-run policies.

4. The knowledge base available to policy-makers, and the need for research, monitoring, and evaluation to fill gaps in understanding and suggest solutions.
5. The impact of changes in policies on externalities.

In concluding these introductory comments we note that the Sub-Committee's response to our earlier 'Issues' paper was to ask us to concentrate more on 'policies'. However, decision-making in agriculture is not simply the prerogative of 'policy-makers', but of many other agencies involved in the industry, and especially of millions of producers. Their private interests may not coincide with those of government, and may even conflict with those of their neighbors. We suspect that failure to achieve the objectives of policy can often be traced to neglect or lack of understanding of the needs of individuals, in plans imposed on them from the top. Policy should not be made in a vacuum, and certainly cannot be implemented in one. While it may not be difficult to suggest policies which apply to individual components of the goal of sustainability, the breadth of the ecological, technical, and socio-economic issues involved and the complexities of their interactions suggests that the problems need to be viewed holistically, perhaps through modelling. Thus we did not find an easy half-way house between preparing a relatively brief 'issues' paper as a basis for discussion for the TAC and a much broader and more detailed analysis of the nature of those issues and related policy measures.

iii) Strategic approaches to a sustainable agriculture.

It is a commonplace that the world as a whole has enough food to maintain its current population at an adequate level of nutrition; and, according to some global estimates of land and water resources and known technological potential, to feed and clothe a much larger population. In a 'one-world' situation, production would be distributed efficiently according to ecological comparative advantage and availability of energy. This, of course, does not mean that there would be no food deficit areas, simply that their requirements could be met from the global food reserve.

Unfortunately, no such Utopian situation currently exists, nor does it seem to be a strong probability in the near future. The world is probably more fragmented nationally now than it was in the nineteenth century, food security is precarious and malnutrition is widespread in many developing countries. Some countries, both in developed and developing regions, have generated food surpluses through technological progress and price incentives, because supply exceeds internal demand. Others, including some of the developing countries which have been most successful in raising production and income growth, have had to increase imports, especially of feed grains, to satisfy changing demands for food and dietary shifts towards livestock products.

Thus, the choice of options to achieve sustainability of agriculture has to take account of a number of different situations on both the demand and the supply side; and is critically dependent on assumptions concerning areas of

uncertainty in formulating the optimum strategy to cope with them. These include:

- The availability of new land and water resources for agriculture, their quality and the cost of their development.

- The state of depletion or degradation of resources already in use, and the opportunity costs of their improvement or reclamation for sustained use.

- The costs of conserving a resource for future use versus its exploitation to meet current demand, even if the latter results in its rapid exhaustion.

- The rate and distribution of population growth.

- The continuity of successful technological progress as an engine of agricultural growth.

- The nature and rapidity of climatic change, and its geographical impact.

- Progress towards a more rational structure of international north-south cooperation.

Depending on judgments as to these assumptions, three strategic options can be postulated for sustainability. These are:

1. To discount the future heavily against the present, even if this means exhausting some resources and depriving future generations of their use. This approach may imply imposing burdens on society today for the sake of larger populations.

2. To follow a strictly conservative approach, which seeks to achieve balanced growth by husbanding resources and prevent any further degradation of the environment by prudent management and where possible to reclaim degraded areas for productive use.

3. An approach which rests on the development of greater complementarities and cooperation between international actions and national efforts as a means of managing the global environment more effectively for higher productivity, allowing for more intensive use of technology in high potential areas, even some resource mining; thus reducing environmental damage by decreasing pressures to produce food or to maintain larger populations in fragile ecological situations.

Option 1. Discounting the future against the present.

A key issue of policy related to sustainability in agriculture is how much should be invested now in actions which will preserve resources for future use, given that the present value of money has to be progressively discounted over time. The

lower the ultimate return to investment, the higher the financial or social cost, and the longer it takes before it begins to pay off, the less attractive the investment compared to alternative near-term uses of the money. Many investments in low-potential areas would only be profitable at a very low discount rate which would be unacceptable to most investors. Similarly, foregoing shorter-term opportunities for exploiting a resource efficiently to optimize the returns on its present worth, and thus increasing the costs of developing it further, may show very poor returns to capital. Thus, the key issue is how much we attempt to extract from a given resource to meet current or immediately foreseeable needs, and how much we attempt to preserve for posterity.

If we discount the future heavily, any non-renewable resources would be exploited to the extent economically feasible in response to demand (even if this involved luxury consumption) possibly to their ultimate exhaustion. This seems to be what is currently happening with fossil fuels, with some water resources ('fossil' water in North Africa), with soils in North America, with the tropical forests and with some semi-arid grazings in Africa.

This 'devil-take-the-hind-most' approach may be tenable and even economically justifiable if it is assumed that technological change will go on raising output in the higher potential environments as it has done dramatically over the last fifty years: that some at least of the short-term environmental damage may be reversible (many ecosystems exhibit surprisingly high recovery from punishment), and that new resources may be discovered or developed in due course to replenish those now

being mined. This has been happening with fossil fuels; but with water the situation in some areas (e.g. parts of the U.S.A.) is growing progressively more serious. It can still be argued, however, that where a finite resource has certain development costs to meet a current level of demand, it makes little sense to use it at some much lower level so that it will be available for mining in fifty years when it might even have been made redundant by technological or climatic change. For example, would the 'fossilwater' under the Sahara be needed if the climate in North Africa was to become much wetters? While these arguments make a plausible case, they tend to ignore inter-regional differences as well as different resource endowments of individual countries, and to take a highly optimistic view of continuing technological gains in high potential areas. Thus, a more beneficial set of international complementarities would need to be developed as part of such a policy to provide security to less well-endowed countries.

Option 2. Preserving resources for posterity: The conservation approach.

A different view would be taken by conservationists, who argue that while some resources might be renewable or restorable, others would be lost irretrievably as a result of a laissez-faire, opportunistic strategy. Some of those lost resources might jeopardize the welfare of future populations, for example plant or animal germplasm useful in agriculture, industry, or medicine. Technological change carries inherent risks and environmental hazards; moreover, the availability of technology

adequate to meet the needs of a much larger global population over the long term is a matter of speculation not certainty.[1]

In view of this uncertainly, mining or mismanagement of any resource simply to maximize present worth is an unjustifiable risk; especially since population doubling is a virtual certainty and climate change a strong possibility. No one knows with certainty whether the latter will transform some areas of low present value into ones of much higher agricultural value fifty years hence. If land has become degraded by misuse, the costs of bringing it back to productive use even in a more favorable climate may be extremely high. This again penalizes future populations in favor of the present. The problem with these arguments is that conservation may be a necessary but not a sufficient condition for meeting present needs, let alone future demand for food. There is obviously a vast philosophical gap between these two views; as there tends to be between some ecologists and anthropologists who fight to preserve any species from extinction, no matter how dubious its value, and to maintain the traditional forms of land management; and some technologists and economists who believe that technical solutions will always keep Malthus at bay and that the changes implied by these solutions should be accommodated not impeded by conservationists.

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1 Does posterity imply one generation ahead, fifty years, or a hundred? Since some investments made now may take at least a generation to mature (irrigation, forestry, research), this seems a reasonable medium-term period. Credible projections of population growth and climatic change suggest an indicative planning horizon of fifty years. However, most senior planners and many people living today will not be alive then. What sacrifices should they be expected to make now to preserve resources for a future they will not see?

Option 3. Fostering national and international complementarities for a sustainable world.

Although planning and implementation of policies to ensure a sustainable agriculture must largely depend on individual countries, more could be done with international cooperation. Ideally, sustainability policies should be formulated to achieve the optimum complementarity between national and international resources. For example, improved understanding of climate, weather forecasting, early warning, of climatic change, and assessment of the extent and state of management of natural resources, would be greatly facilitated by an effective combination of global sensing using international equipment and analytical expertise, supported by ground observations and recording by individual nations. International and national agricultural research systems are complementary and mutually supportive. Food security can be enhanced both by emergency support through international food aid and disaster relief efforts; by guarantees such as the IMF food facility scheme, by trade liberalization agreements and by regional integration efforts among groups of countries. We shall deal in more detail with some of the possibilities later in this paper.

More difficult, but still feasible by mutual agreement among countries, is the prevention of laissez-faire exploitation of resources by individual countries (or groups of countries), which threatens sustainability in others, or even global security. Nuclear war is probably the ultimate example and the most

difficult to stop once the chain of events leading to it is in motion, as World Wars I and II demonstrated.

But other and more insidious externalities exist: atmospheric pollution leading to climatic change; destruction of vegetation cover, especially in semi-arid areas and tropical rain forests which may contribute to climatic deterioration; nuclear accidents of the Chernobyl scale; and more localized industrial pollution (acid rain, river or oceanic pollution). Ironically, while international action is generally easy to mobilize to help with natural emergencies such as earthquakes or volcanic eruptions, it is often much more difficult to achieve agreement on how to prevent disasters arising from human error. Another irony of a rather similar nature relates to the tariff and non-tariff barriers erected by developed countries to trade with developing countries; to which those same developed countries are channeling considerable sums in funds for development assistance.

An important objective of future strategies to maintain a sustainable agriculture should, therefore, be to improve the complementarities between national, regional, and international policies and actions; to develop more effective machinery for global environmental monitoring and action to help prevent damaging externalities, as well as for consultation to achieve rational trade agreements which would eliminate paradoxes of the type outlined above. As an IFFRI study on cooperation in Southern Africa shows, the potential benefits of greater cooperation among countries go beyond trade and food security, they facilitate more logical resource use and exploitation of comparative advantage for production. By concentrating

agricultural development efforts and raising employment opportunities in more favorable areas, this type of mutually supportive cooperation may reduce pressures on the more fragile environments without having to introduce draconian measures of resettlement or control of movement, or high-cost/low-return investments in land reclamation and other conservation tactics.

This is not to say that mining of non-renewable resources or damage from misuse of technology could always be avoided through this more integrated approach to sustainability. Nevertheless the pooling of national and supra-national resources would provide early warnings of environmental hazards and hopefully would reduce the chances of 'why them and not us' confrontations between countries in dealing with externalities, thus providing greater insurance against individual irresponsibility threatening sustainability on a much wider scale.'

The main snags are that this approach may imply some loss of national sovereignty and greater sharing of knowledge and information, which could be unacceptable to some countries. Thus it, too, may be somewhat Utopian. However, all these policies and measures do not have to be implemented in parallel; and if the pressure on resources does not build up abruptly, (due for example to sudden climatic deterioration, or accelerated population growth), the inexorable progression of events will probably force even the most reluctant nation-states to cooperate more effectively with others over time. This approach appears to offer a middle-of-the-road strategy which avoids the high risks implied by technical opportunism while giving a better change of meeting future needs than ecological theology.

In concluding this introductory session, we feel a need to draw attention to the fact that the goal of sustainability is not new, even if its explicit recognition by development assistance agencies and the GGIAR is. Sustainability is implicit in many of the practises followed by agriculturalists since time immemorial, although they have not always proved successful. Thus, we wonder what underlies this new thrust in development policy, and whether the various proponents of it see eye-to-eye as to its meaning. This is why a clear and agreed definition is necessary. What separates this from other development concerns? Why is it deemed that the normal process of perception, trial and error, research and adjustment which goes on within the CG system and in other relevant institutions will be inadequate to the task?

We hope that this is not just some new fad in thinking about development policy, which itself will not be sustainable, or that it is seen as a convenient argument to justify smaller aid budgets, requiring less expenditure of capital.

Our belief, however, is that this sudden concern reflects a genuine awareness and alarm that many of the traditional measures devised by agricultural practitioners to safeguard sustainability are breaking down, and that processes of resolution different from those currently, in place, and perhaps more equitable, are needed. In order to understand what these may be and their implications for policy we need:

1) to know more about current agricultural systems; where and for what reasons they are failing;

2) where the areas of high risk are and the causes;

3) how to counter intergroup or inter-temporal externalities resulting from present actions which may jeopardize future agricultural potential, and if possible, to internalize them through institutional and other mechanisms; and

4) how to acquire more comprehensive, precise, and timely information on sustainability problems and progress in finding new technical or other solutions, so that remedial policies and related actions are not delayed until it is too late. Since there are signs that the world is moving into an era of greater uncertainty better understanding of the processes of change is vital.

PART 2

Climate

Major climatic influences affecting sustainability

Climate is a resource (although it is not always recognized as one). Indeed, in the past it has probably been the main natural resource determining the geographical distribution of crops and ruminant livestock, as well as the absolute levels of mean yields. Even today, despite the pervasive influence of modern agricultural technology in the industrialized countries, and its growing importance in the developing countries; there are large areas of the world, especially in Sub-Saharan Africa and tropical South America, where climate remains the dominant factor. Thus its importance in the context of sustainability is paramount.

Climate is not uniform spatially or temporally. The dominant features determining macroclimates are moisture and temperature, but their effects may be modified geographically by factors such as latitude, or locally by soil, slope, and altitude. Thus the mean annual rainfall in eastern England and northern Nigeria is about the same but its distribution across the year and seasonality in relation to temperature is very different, with much greater variability and risk in Nigeria. Technology must therefore be tailored to take account of these differences, with obvious implications for research.

Four types of climatic influence may have to be considered in relation to the achievement of a sustainable agricultural sector in the short and longer term. These are, in order of permanence;

i) Emergencies caused by short-term climatic shocks. These normally include hurricanes, typhoons, cyclones, massive floods and tidal waves. Exceptionally earthquakes and volcanic eruptions can trigger such emergencies: the former usually through oceanic disturbancies, the latter through dust effects in the upper atmosphere. A new, and potentially more dangerous and persistent hazard is 'nuclear winter.'

ii) Inter-annual climatic variability. Climatic variability from season-to-season is a feature of every major climate, but some major climates exhibit much greater variability than others. Low rainfall regions with extremes of cold or heat, (for example the summer rainfall semi-arid tropics and the Mediterranean winter rainfall sub-tropics), tend to have high coefficients of variability of yield; compared either to the warm temperate zone or the wetter tropics and sub-tropics. Countries, covering a large spectrum of latitude or altitude may include areas with several different agroclimatic zones, and this may help to buffer risks due to high variability (see Desai 1986 concerning the USSR, and the relatively low overall c.v.'s for China, India, and the USA). Smaller countries located mainly or entirely in climatic zones characterized by high variability may be extremely vulnerable.

Much of the research and other strategy devised by planners and policymakers, as well as by producers, is aimed at countering or mitigating these year-to-year weather variations. In addition to measures related to increasing or improving the stability of production, action outside production to ensure greater food security for the mass of the population is also essential.

iii) Climatic fluctuations. These are periodic shifts in climatic patterns, lasting for several years or even decades. They may influence large geographical regions or even be of a global nature, but they are not of permanent significance.

Thus, while the world has been experiencing a relatively benign climate over the present century, with a mild warming trend (0.5°C since 1900), there was a temporary reversal of this trend between 1940 and 1970 which caused considerable dissension among climatologists as to what would happen in the future.

Of greater immediate importance is the marked deterioration since 1970 in the regional climate of the semi-arid tropics of West Africa. Studies by Wigley, Nicholson, Lamb and others show a convincing pattern of decreased rainfall and increased intra-annual variability in the Sahelian zone, which has led, inter alia to a southward shift of as much as 100 km in the main producing areas of key crops such as groundnuts in Senegal and Burkina Fasso. No adequate explanation has been found for this change, which goes much beyond a short series of anomalously variable years. It has been suggested but not proven that it may be due to an increase in albedo, resulting from over-grazing, removal of tree cover, and eventual desertification; a feedback from earth to sky. If this is the case it indicates a vicious

circle of interaction between an extreme climate and extreme pressure on resources where each makes the other progressively worse. It is important to note that the longer an adverse climatic anomaly continues in a fragile and vulnerable environmental, the more difficult it is to avoid permanent damage to the natural resource base. In this context, and more generally with respect to variability, it should be noted that a majority of the traditional agricultural practises developed over millennia reflects attempts to manipulate, mitigate or avoid unpredictable climatic hazards; these practises include nomadism, transhumance, shifting cultivation, and bush fallowing; terracing, bunding, mulching, shelter belts and other soil/water conservation practises; drainage, irrigation, flood control, and water-spreading devices; as well as the use of crop cultivars or breeds of livestock adapted to or tolerant of specific climatic situations, and cultivation methods which offer some insurance against climatic risks. The latter include varying sowing and harvesting dates, mixed cropping, inter-cropping, and layering. A number of these attempts to reduce the impact of adverse climatic factors depended on spatial flexibility;, most relied on human labour more than on chemical or mechanical technology, and in some cases on sharing of land and/or labour to provide mutual security. Their ingenuity has enabled an increasing population to sustain life for centuries in a wide range of environments, where climate and particularly its short-term fluctuation has dominated their livelihood, and yet to remain in relative balance with their natural resource endowments. A final gambit to

survive is to sell capital assets; livestock, land, or both: hence the widely fluctuating animal numbers in high-risk areas.

Many of these traditional safeguards are now breaking down under pressures of excessive human and livestock population, inadequate technology, urban competition; exacerbated by rising labor costs relative to rural labour productivity, falling prices for primary products, and in some cases political restraints.

iv) Climatic change. While planners and policymakers cannot very well ignore the benefits, limitations, or demands placed on their resources by their existing climate and its variability; most tend to assume climate as a constant in longer-term planning. This is convenient; it avoids introducing further complex variables into models, and past schisms among climatologists as to whether the world is entering a warming or cooling phase provide an excellent argument for non-experts to avoid the issue. Moreover, it is also often assumed that while human action may be able to take some defensive or precautionary measures to offset relatively predictable or recurrent climatic shocks, man's ability to manipulate, influence, or forecast long-term events is insignificant.

It is now clear that both of these assumptions are in many respects wrong and that although there are large areas of uncertainty as to the future, to go on assuming that global climate will remain cast in the relatively benign mould of 1945-85 for another 40 years is an unwise base for planning a sustainable future.

Quite apart from the increasing evidence that the measures which have enabled rural populations to survive and to sustain agriculture in reasonable balance with resource endowments by manipulating a climate -dominated resource base are no longer adequate; there is now an important weight of scientific evidence pointing to a significant warming trend in world climate over the next 50 years as a result of anthropogenic influences. While the main cause is the release of CO_2 and other gases of industrial origin into the atmosphere, increased albedo due to removal of vegetation in range and forest lands, and smoke from fires ignited for land clearing, cooking etc.: by an increasing population are held to be contributory factors.

The overall impact on climatic warming is predicted to exceed anything in the last 10,000 years. The average global mean temperature could increase by 2-3°C by the year 2050: the increase at the poles would be greatest. The probable effects of this on precipitation are not yet well understood; but it is certain that the centre of gravity of some key producing areas will shift as a result of increasing dryness, while some which are now relatively drought-prone will become wetter. Moreover, because of the lagged effects of the heat-absorption capacity of the oceans it is unlikely that these anticipated changes could be stopped even if all abnormal CO_2 emissions were to be halted now.

Thus planning which envisages actions or investments likely to affect agriculture and resource management fifteen years or

more into the future - large-scale irrigation, land reclamation, tree crop planting, and many research projects, needs to pay careful attention to the growing weight and direction of current scientific evidence on climate change.

It is also likely that a change of the magnitude now foreseen by climatologists will be accompanied by an increase in inter-annual weather variability affecting crop yields. Initially this may make the direction and certainty of change more difficult to identify. In addition, even if relative variability were to remain much as it is today, the absolute magnitudes of a given deviation from the mean will increase as the overall volume of production increases. A third complication arises from the influence that any major shift in climate may exert on the so-called 'teleconnections'. This is a phenomenon recognized only recently whereby a climatic anomaly in one area of the globe causes weather anomalies in one or more distant regions, usually with a time-lag. These anomalies are not necessarily in the same direction in the different regions affected, one may be wetter-another drier. The two most commonly recognized teleconnections are the ENSO (El Nino-Southern Oscillation) link between directional changes in oceanic currents off Western South America, and atmospheric circulation patterns over the Pacific and Indian Oceans; and the 'blocking' of the Westerlies over the Atlantic which leads to extremes of warm/dry or wet/cold years over Europe and parts of the USSR, and which may also affect weather over West and North Africa. Historical tracking of rainfall and temperature in ENSO and non-ENSO

affected years for parts of Canada, the U.S., Central America, and the Caribbean covering the period 1815-1915 shows striking intra-regional correlations between weather and ENSO phenomena. Much remains to be learnt about these important teleconnections within current world climate: as yet we have no idea what influence climatic change might have on them.

Policy Implications

1. Approaches to decision making.

Since the influence of climate is not uniform, but variable both temporally and spatially, a set of policies has to be devised to cope with the consequences. These policies involve a mix of national and international actions, although ultimately their implementation must rest mainly on the shoulders of individual nations.

The necessary policies and related actions can probably best be classified in terms of the four main types of climatic influence described above (short-term emergencies, inter-annual or short-term climatic variability, longer-term climatic fluctuations, and climatic change). This offers two advantages: first, it provides a time-phased sequence for planning purposes; secondly, it enables policies to be related to specific geoclimatic regions, since the areas principally affected by each of these four types of influence are not the same, and it is possible to identify geographical regions of maximum actual or potential vulnerability to each type. This could both help to

indicate the approaches most likely to be beneficial in each region, and to facilitate decisions as to short and longer-term priorities between and within regions.

2. Identification of high-risk areas.

A preliminary grouping of broad geoclimatic regions by degree of risk for each of the four categories of climatic influence is shown in Table 1 is suggested below:

i) Climatic Emergencies. While regions located primarily in the humid tropics of Asia, the Pacific and the Central America/ Caribbean regions are particularly at risk to short-term climatic shocks, such as hurricanes, typhoons, cyclones, and floods, those regions have relatively low inter-annual climatic variability measured over longer periods of time.

ii) Areas of high inter-annual variability. Conversely, the semi-arid summer rainfall regions of the tropics, and the winter rainfall sub-tropics (Mediterranean climate) which both have very high inter-annual climatic variability, are not as likely as the very wet regions to experience violent short-term climatic disasters. Cold countries at high latitudes (Canada, Scandinavia, Northern USSR); or plateau regions in continental Asia (China, Mongolia, Central Asian USSR, Iran, Afghanistan, Turkey), or parts of North America, which experience extremes both of cold and drought, also tend to have highly variable but relatively non-violent weather. However, in terms of population dependency, the semi-arid, tropical regions of Africa are probably the main area at high risk, because climatic insecurity

there is aggravated by a high proportion of low-income countries, a low proportion of irrigated land, lack of good rainfed technology, and a relatively large nomadic population. Semi-arid South Asia, which also has a highly variable climate and many low-income people is better served by research, irrigation, infrastructure, and institutional support to agriculture; these factors have combined to provide greater security against famine in recent years. Nevertheless its massive population gives cause for concern should a prolonged period of adverse weather eventuate; and the current heavy focus of international research and development assistance on Africa should not obscure the risks inherent in loss of sustainability in South Asia.

Although some countries in the Mediterranean climatic zone probably suffer an even higher degree of inter-annual variability than the semi-arid tropics, and this zone also has a large population mainly in developing countries, most of them are middle-income countries with relatively low dependence on agriculture. With the exception of Central Asia and China, the cold marginal populations are largely located in developed countries which depend for food security on technological progress and on trade.

(iii) Areas of intermediate duration climatic fluctuation. This is the most difficult situation to identify and thus to cope with by timely policies. Such an anomaly may demand little or no policy measures if it occurs in a region of relatively high inherent stability and low vulnerability (for example a moderate drying trend in the humid tropics of Equatorial Africa or a somewhat cooler/wetter regime in the U.S. corn belt). Indeed

Thompson has shown that the latter could be closer to the optimum for corn than the actual longer-term average of temperature and precipitation for that region. However if a climatic shift adversely affects a region or regions which are already highly variable, and near the margin for settled agriculture, then it may be much more serious; the more so if any or all the affected area is densely populated in relation to its optimum carrying capacity under the more favorable climatic regime prior to its deterioration.

While such situations call for urgent measures, the type of action needed to increase sustainability in terms of production may require substantial investment in research, irrigation, and infrastructure and possibly even resettlement - none of which can be expected to provide an immediate payoff in terms of stability or financial benefit, and which may in some cases require a long time to mature. Thus the initial reaction of policymakers is to wait and hope that the adverse weather trend is short-lived. It is difficult to blame them for this, even though every year's delay may make a deteriorating environment more difficult to manage, since few climatologists would be so rash as to assert that three or four poor years heralded a trend likely to persist for another six or more.

Yet this seems to be basically what has occurred in Sahelian West Africa, as the pattern of precipitation since 1970 clearly shows. So far this is the only major geoclimatic region where it is now widely accepted that there has been a positive

deterioration in climate in recent years; although there have been suggestions that the frequency of poor monsoons in India is declining, and that the climate of Western Europe has become wetter.

iv) Areas likely to suffer adversely from climate change. These will, of course, differ according to the general global trend; but given the widely-accepted probability both of higher CO_2 content in the ambient air and a global warming trend there is an expectation that C_3 plants will benefit more than C_4 plants, due to enhanced photosynthesis (which might favor wheat, barley, and rice, more than sorghum, maize and sugar-cane); but that water-use efficiency will be increased in both C_3 and C_4 species. Regional effects of climatic warming are likely to be most dramatic in high latitudes and lowest in equatorial regions, although coastal lowlands in the latter might suffer increased risk of flooding if sea levels rise due to ice melt.

The impact on precipitation is more speculative, but there seems to be a considerable measure of agreement that the U.S. Corn Belt is likely to become drier as well as warmer, pushing the optimum climatic zone for corn production further north. This, however, would probably extend into an area of podzolic soils, hence yields might fall. Because of the present high dependence of the majority of food deficit countries on grain reserves from mid-latitude temperate countries, particularly the United States, any long-term climatic threat to the sustainability of grain production in those countries is of the utmost gravity.

Thus the regional priorities for research and international food security policies to counter such a threat may be different from those required to deal with shorter term climatic hazards, especially those resulting from high relative inter-annual variability. In either situation, however, it seems likely that the Sahelian zone of Africa will remain a priority area; whereas there are indications that India and the USSR might be better off as a result of climatic warming.

3. Policies to improve sustainability and related issues.

In any of the four situations described above improved weather forecasting and tracking of trends in order to provide early warning of the nature, direction, and magnitude of climatic shocks, is likely to be beneficial. In many developing countries meteorological services are weakly staffed and not trained agriculturally; efforts have often been directed largely towards the needs of aviation and, sometimes of tourism. Timely transmission of weather information to rural people still causes problems, although the wider use of transistor radios is helping to overcome these. Timely warning is particularly valuable in the case of sudden emergencies. Although it is sometimes felt that little can be done to prevent damage and loss of life from cyclones, hurricanes etc., these storms do tend to be concentrated largely in relatively restricted geographical regions and at specific seasons of the year. Once a storm hits an area disaster may be unavoidable but a good deal can be done

to mitigate its worst effects on individuals if some advanced notice can be given. The policies adopted are likely to involve measures to conserve emergency food supplies, maintain medical, power, and other vital services, prevent civil disorders, and perhaps to introduce and enforce evacuation and other controls on movement of people and traffic.

Because of the violence and short-term nature of such events, action to sustain agricultural production is often impractical until after the emergency itself is over; when measures may be necessary to repair damage by floods or high winds, replant trees, rebuild farm property, restore water supplies, and communications, and provide financial assistance to help local communities or individuals put things back together. It is even possible that changes in cropping patterns, planting of windbreaks etc: may be introduced to reduce future losses.

Governments may seek and often readily obtain international assistance to cope with the most immediate effects of such disasters, especially if they occur in small countries. Longer-term aid, for example to rehabilitate agriculture, is not always seen as a priority by donors because of other pressing calls on their resources, and the country may have to under-take this from its own resources.

<u>High climatic variability</u> is often difficult to distinguish in the short term from intermediate medium-term climatic fluctuations and the policies required to sustain agricultural

production where they are prevalent are not dissimilar. They include in the shorter term:

- Establishment of strategically sited food storage and distribution points in relation to areas of high vulnerability, and maintenance of reserve stocks there.
- Improvement of transport, communications, and road and vehicle maintenance facilities 'downstream' from storage points to ports or central storage, and 'upstream' to main areas likely to be served in an emergency. The establishment of food-for-work programs in relation to road-building should be part of such a policy. The communications network should also be capable of handling movements of domestic food production in an emergency, especially livestock.
- Commercial food imports or food aid may be obtained to bridge gaps in domestic production of staple foods. There are nevertheless, several dangers in such measures, e.g. Imports may sometimes be available at lower prices than their protein/calorie equivalent can be produced locally, especially if the imports are subsidized by exporting countries or provided on some form of concessional terms. Unless sold locally at prices compatible with local

production costs they may depress incentives to increase domestic production, especially if this involves higher cash costs and/or greater risks.

- Imports do not always reach vulnerable people and/or vulnerable areas, but get diverted to urban centers or privileged groups of consumers.
- Imports may shift dietary preferences towards commodities which are convenient for urban consumers, but cannot be produced in adequate amounts locally for ecological reasons. This has particularly been the case with wheat imports to Sub-Saharan Africa. Not only does this dependence cause political problems once production of traditional local staples recovers, but it poses difficult issues of priorities for research policy.

In areas where high inter-annual climatic variability regularly threatens sustainability, it may be prudent to plan and to implement some policies as a permanent counter-attack to a known element of risk. The policies required are likely to involve mix of short and longer term measures; including in the latter case:

- Emphasis in research, and especially in breeding programmes, on measures to increase stress tolerance in plants and animals, and on cultural (weed control,

water conservation) or other practises (alley cropping, intercropping) which buffer variability and reduce risk. Particular emphasis may need to be placed on measures which conserve soil structure and fertility without demanding high cash inputs.

- Establishment of efficient seed production and distribution services, providing a range of crops and cultivars, designed to give maximum flexibility to farmers in choice of crops, varieties, sowing and harvesting dates.
- Development of water resources, both for irrigation and for drinking purposes (human and animal). This can involve both surface and ground water, and 'water harvesting'. A problem with larger schemes and with deep wells is the location of the resource in relation to the areas and populations most threatened by variability, especially drought. In some cases it may be necessary to couple irrigation development with resettlement policies. Quite apart from the time it may take to develop a sustainable agriculture when people inexperienced with water use are settled in irrigation schemes the costs are likely to be high. The opportunity costs of such large and probably slow-maturing investments have to be weighed against alternative uses of the funds.
- Development of fiscal and other economic measures which provide incentives to innovate even in higher risk areas, as well as offering some insurance of relief for

situations where weather adversity threatens sustainability of production or life itself. Work at IFPRI and elsewhere does not suggest that crop insurance per se is a viable solution to encouraging innovation in such circumstances: but realistic price support policies, low-cost credit, debt servicing alleviation and tax remission, especially on agricultural products, may be feasible. In this connection it is worth noting that while grain and feed prices tend to rise in a drought situation, livestock prices usually fall. The difficulty of keeping breeding herds intact in an emergency is thus compounded by price differentials.

Contingency plans can be made for a package of such measures; and these and/or some form of central or federal disaster grants may be applied to severely affected regions but not necessarily nation-wide.

In this connection it is worth noting that not only are some policies easier to implement in an emergency than others, but some (whether easy to introduce or not) are difficult to reverse once the emergency is over, and some are virtually irreversible. For example input subsidies, while fairly easy to introduce, are often a source of political problems when attempts are made to discontinue them. Industrial projects, especially those dependent on a critical mass of agricultural raw materials, can

be difficult to sustain if mislocated, but to shut them down may involve a large political risk.

Large-scale dams, irrigation systems, and settlement schemes cannot be abandoned halfway although they may sometimes be scaled down. Roads, once in place, are permanent unless so badly maintained that they become unusable. Most policy measures, including institutional innovations, imply recurrent expenditure if their viability is to be sustained.

We shall return to this aspect of sustainability later; but when planning a set of policies to deal with contingencies involving different time horizons, and degrees of certainty as to their occurrence, such as those posed by climatic variability and climatic change it is obvious that decision-makers face a considerable problem of balancing too much and too soon against too little and too late! Deciding what must be implemented to provide an immediate but perhaps minimal level of food security, what should be done over the longer term <u>anyway</u> as part of a prudent policy to provide a more secure and sustainable agricultural base, and what might have to be done in time should climate deteriorate, involves delicate judgment as to what plans to put into operation and what to leave on the shelf.

It seems reasonable to assume that priority will be given by bilateral and international donors during the rest of this century to improving or at least maintaining sustainability of agricultural production and food security in the more

climatically vulnerable developing countries. If this is the case then the risks of recurrent human catastrophes such as the Bangladesh, Ethiopian, and Sahelian famines should be reduced.

A related and difficult policy issue, is how the goal of a sustainable agriculture might best be attained: whether by action in the areas most directly affected by climatic instability, or in the areas which are more suited to intensive production and the application of modern agricultural technology. The latter might provide a more reliable base of national food security while relieving some of the pressure on the more risky areas; whether it would do much directly to help the people living in those areas or to reduce the level of environmental damage currently threatening sustainability there (and possibly, through externalities, in the better areas too), seems much less certain.

This is important not merely with respect to the environmental issues, but also to human well-being. Lack of purchasing power among the poor is a major reason for malnutrition, and it seems reasonable to assume that a higher proportion of the really poor, although not necessarily of the total population, will live in the ecologically disadvantaged areas than in those better-endowed in terms of climate, soil and water resources. This assumption merits empirical testing, but if it is correct strong employment linkages will be required between disadvantaged and advantaged areas if a focus of development efforts on the latter is to benefit the former. It

is important to ascertain to what extent these exist; if not, how they can be created.

Since 1980 the research effort devoted to the study of climatic change has increased enormously. How should policy-makers react to the mounting scientific evidence pointing to an accelerated global warming trend over the next half century? Although this is largely attributed to anthropogenic influences it appears to be outside human power to halt this trend, although swift and sweeping action to control industrial and other emissions might reduce its long-term magnitude.

To ignore the warning signs would be foolish: on the other hand the probable regional and local effects of the predicted increase in temperature are still a matter of conjecture and those on precipitation are even less clear. To make large precautionary investments in this climate of uncertainty when other more immediate calls on available resources require funding would therefore also seem unwise. This does not mean that no action should be taken to identify and attempt to limit the main sources of the hazard even if there will be short-term social and economic costs, and only long-term benefits. Otherwise an uncontrollable situation might arise. The costs of additional research might be met from public budgets: those of control by taxes on the main agents of pollution.

From the point of view of sustaining agricultural development it is questionable whether specific action other than

enhanced research in climatology and agroclimatology is merited before the year 2000. What is required is closer monitoring and evaluation of key climatic parameters, accompanied by improved characterization of agro-ecological zones, current land use, and levels of resource degradation in those zones. Thus any changes in climate, as well as increases in variability or frequency of anomalies or storm intensities could be identified sooner and their intra and inter-country impact assessed. Empirical statistical data thus obtained, together with analysis of historical climatic records, can be used to improve weather forecasting, as well as to aid diagnosis and prediction of the direction and geographical impact of climatic change by providing inputs to simulation studies, climatic modelling, and model validation. Progress in understanding the interactions between oceanic and atmospheric influences through General Circulation Models should ultimately land to a deeper understanding of the global factors affecting climate and weather.

The cost of reinforced international monitoring, research, and evaluation of climatic data and its implications for a sustainable agriculture; which, inter alia implies a substantial strengthen of meteorological data-gathering and analytical capacity in developing countries, may be considerable in absolute terms. It is nevertheless likely to be very small in relation to the precision it could eventually provide to development policy in a changing world.

PART 3

Land Resources and Their Management for Sustainability

The Importance of Land as a Resource

Land is the basic resource for agriculture. Wherever moisture or temperature are not critically limiting to plant growth, the availability of land and its characteristics largely determine what can be grown, what level of production is attainable from a given area with traditional cultural practises, and what scope exists for improvement through the introduction of different methods of management and technological change.

Land is also a commodity; unlike soil, which is not. Even though soil quality and fertility are the main factors determining the agricultural value of land, what can be grown on it, and how it should be managed for sustainable use; soil is not the only determinant of value. Slope, aspect, altitude, and accessibility are also important, and while fertile land far from main markets may have limited value, land of inferior quality closer to a city may be worth more for agriculture, and land of little or no intrinsic worth suitable for building may be worth a fortune.

Because of its central role in agriculture, whether for crops, livestock, or forests, land has enormous social and economic importance; and even though it has frequently been mis-managed either out of ignorance, short-sightedness, greed, or

as a consequence of war, disease, or other exogenous factors, much care and ingenuity has been devoted historically to devising means of preserving its productivity. Although bush-fallowing, shifting cultivation and migratory systems of animal husbandry have been condemned as exploitive and damaging forms of land use, they were in fact conservative systems within their historical context. That they no longer serve their original purpose in a more densely populated, urbanized, and nationalistic world is not a reason either for perpetuating or condemning them; but rather for incorporating the beneficial principles of traditional systems of sustainable land management into new systems more attuned to present socio-economic needs, while avoiding repetition of past mistakes.

Because land is the only tangible asset of many rural people, it has a social and psychological importance to its owners which may exceed its intrinsic worth or market value. Thus it has often been a source of conflict at all levels of society. In many developing countries land is also the principal theoretical source of taxable revenue; although because many holdings are so small, governments are often reluctant to impose land taxes both for fear of political unrest and because of difficulties and costs of revenue collection. Nevertheless, in view of the economic importance of land, the intensive competition for new land in many countries, and the social consequences of its loss, it is surprising that it is so widely abused and mismanaged; and also that governments have not devised

means of providing incentives to correct or prevent these abuses, particularly if this might yield additional fiscal revenue.

Principal Causes of Lack of Sustainability in Land Use

There are six principal sources of destabilisation of land resources. These are:

1. Natural factors: Including tectonic influences, mainly in mountainous areas of relatively young geological origin... the Himalayas, Andes, Alps, and Mediterranean Basin: climatic shocks such as flooding, wind damage; and climatic change leading to changes in vegetation cover, and possibly - if the warming trend continues as predicted, to loss of land at sea-level from melting ice. As a rule undisturbed ecosystems outside mountain areas, even on so-called fragile soils, are not prone to sudden change or deterioration, although sometimes an excessive build-up of wild grazing animals can cause damage.

2. Overgrazing: This is a principal cause of biomass deterioration, both in terms of quantity and quality in marginal soils and in both semi-arid and very wet regions. While the effects are not necessarily irreversible, and traditional grazing management practises, especially in semi-arid and mountain regions, tend to have built-in safeguards against ruining the resource on which their livelihood depends; excessive, unremitting pressure leads to desertification. It is important to note also, that while the main agents of this process may be the pastoralists, other pressures also contribute. These include fuelwood gathering, creeping inroads of cultivators into areas

better devoted to grazing; and in the case of the equatorial forests, initial removal of tree cover by loggers or cultivators, with grazing being a last resort in land abandoned for other use.

3. Deforestation: This may occur in a wide range of environments, and is proceeding at a rate roughly ten times that of reforestation. Estimates of the effects of loss of tree cover in semi-arid and sub-humid zones seem hard to come by: most attention has been focused on the equatorial rain forests (especially in Amazonia) because of fears of genetic erosion and of climatic deterioration, consequent on large-scale removal. While it is generally assumed that the influence on climate will be detrimental the evidence so far is inconclusive, and perhaps the main reason for great caution is that once it is conclusive it may be too late to do anything to reverse the situation.

Many different agents of change are at work in forest areas, and most are not new. They include bush fallow systems of farming - not a bad form of environmental management when the fallow is long enough to restore fertility; and other, much more damaging, attempts to grow crops in areas of cleared forest; slash, burn, and move on, sedentary farming without adequate fertilizer, weed, or erosion control; grazing cleared areas, either after cropping has failed, or directly after tree removal; or simply damage to tress and prevention of natural regrowth of seedlings by excessive grazing and fuel gathering in forested mountain watersheds without any clearing, as in the Mediterranean Basin. Plato, in his Critea, written in 400 BC, gives probably the most

graphic and accurate description of the ecological, social, and economic evils - including the externalities, of deforestation in that environment. The main modern agent of change is the introduction of mechanical road construction, clearing, and logging equipment which not only facilitates more rapid exploitation of the resource, but also access of graziers and cultivators to areas from which they were previously excluded by their remoteness. The fate of the land thereafter may depend largely on the willingness of those who removed the timber to replant and continue to manage the area for forestry.

A problem affecting both forested land and grazings is that they are often seen as common property, either by tribal inheritance, or by villagers themselves. These commons may provide the entire livelihood of a community, or they may be an adjunct to some cropland. They are particularly valuable as a source of income to landless people and women. Customary rights over land are steadily being eroded by enclosure, state intervention, by cultivation, ranching schemes and by restrictions on movement of people and animals nationally and internationally. The use and correct management of communally-used areas thus presents difficult human and technical problems.

4. Technological Change. This can be both beneficial or detrimental to sustainable land use; but it is not confined solely to the practise of agriculture.

As mentioned above road building can significantly alter land use in cleared forests; similar influences have been demonstrated in pastoral areas; where cross-country trucking of

livestock even in areas of poor or non-existent roads can extend accessibility of animals to grazing areas, and may circumvent traditional rotational grazing practises of nomadic pastoralists, which provide at least some respite from continual overgrazing. For similar reasons the extension of water points by the use of modern mobile drilling rigs has become a controversial issue.

The aspects of agricultural technology affecting sustainability of the land resource are principally those which influence the maintenance or improvement of soil fertility and structure, or lead to its degradation. Their importance is crucial to developing countries, since the FAO AT 2000 study and related work by FAO jointly with UNEP, & IISA shows clearly that sustainability of food production in many countries of the Third World, depends to a large degree on raising levels of soil fertility.

The principal source of growth envisaged by these studies is fertilizer in conjunction with the use of improved varieties. Pest, disease, and weed control is also considered important, but the variety fertilizer interaction is the key. We will deal in more depth with this later.

Less explicit, but nevertheless vital, is the maintenance of the soil structure as a medium for water and fertilizer use, and the support of plant growth. Thus measures to prevent physical degradation of soil, and if possible to improve it, are also essential. A related problem is how to improve the soil organic matter status: a problem not adequately addressed in the FAO studies, and one which few national or international research programs have come up with economically and technically viable

answers. In the general context of soil management, the role of mechanisation is probably the most controversial issue, especially with respect to soil erosion and loss of organic matter. The experience of the 1930's in the United States, and the 1950's in East Africa, shows machinery to be as susceptible to inexperienced handling by western agriculturalists as by people from developing countries. Indeed, in the wider sense, including its impact on forestry, animal production, crop husbandry, post-harvest processing, irrigation development, and infrastructure, mechanical technology may be the most pervasive of all anthropogenic influences on sustainability.

Apart from the prevention of physical loss of structure from wind or water erosion; (whether due to forestry, grazing, mechanisation or 'natural causes') it is also necessary to avoid polluting soil (or water) through excessive or incorrect application of fertilizers, pesticides, or other toxic agents.

So far this has been mainly a problem of advanced technological societies - including effects of agricultural chemicals and major influences not directly connected with agriculture but impacting on it (externalities), such as nuclear accidents, acid rain, use of detergents, and air pollution. Developing countries have suffered more from the physical damage to soil characteristics described above; but some have now moved to levels of industrial and agricultural technology, where sustainability may be threatened seriously by damage of mechanical or chemical origin as well as more traditional agricultural sources. Technology may potentially be the main prop of sustainability and

the salvation of the human race, but it is not without dangers. 'Handle with care', should be the watch word.

5. Urbanization: Urbanization, including major road construction, energy and water use, competes with agriculture for productive resources - and usually wins. Fortunately land which is useless for farming can often be used for building; but urban developers seem rarely to have been swayed by reluctance to use prime arable land for urban use, especially if it is simpler or more convenient to their planning to do so. The extra agricultural land value is of small importance compared to its built-on value, and the compensatory return to the landowner may be far more than he could ever earn from farming. Moreover, in many cases the spectre of compulsory purchase orders underlies decisions to sell.

Urbanization is likely to take increasing amounts of land out of agriculture in the Third World countries, as it has in the industrial countries. Shanty towns are a major problem in countries with rapid population growth; reflecting the magnetic pull of the cities for employment and amenities. The development of linkages between rural and urban areas for farm produce, industry, and part-time off-farm employment is a more hopeful side of the problem of urbanization; and one which needs to be fostered. There is some danger that drift of younger workers from the land will lead to shortages of labor at peak periods in more remote areas which will threaten sustainability, especially in Africa where labor productivity is generally very

low. Experience there so far does not suggest that large-scale mechanization is the answer.

6. Human Pressures: Generally speaking, the main threat to sustainability seems to be the extension of cultivation to areas which are at best marginal to settled agriculture, and without any of the safeguards or inputs which might render it sustainable. Thus in semi-arid areas reasonably good and stable pasture is converted into poor cropland, while the remaining grazing areas become marginal under the squeeze of increasing grazing pressure. Similarly good, productive forest land in tropical high-rainfall areas, is being converted progressively into poor crop land, degraded grazing, and virtually useless scrub, as water erodes the soil and organic matter and fertility are lost. In mountain areas cultivation on steep slopes without terracing or other checks leads to both sheet and gully erosion; although grazing or trampling by livestock may also be a destabilising influence, especially if trees are prevented from regenerating. The extent to which those effects have been accelerated in developing countries by modern practices and by large-scale commercial enterprises (except in the case of timber extraction is uncertain), their influence may be increasing, but currently the main threat to sustainability is poverty, unequal or no access to land, inequitable access to (or sometimes unavailability) of other factors of production (credit, machinery, water, fertilizer, energy, labor), and inadequate awareness of new techniques of production which might make life more sustainable, as a result of institutional and political

instability. Excessive population growth is often seen as a major contributory factor to these inequities.

Policy Issues and Research Needs:

The proceeding analysis reveals some tough and apparently intractable issues related to sustainable land use, many of which are also complex and controversial. Some of those which appear most important and which require further research will now be briefly reviewed, but the list is by no means exhaustive.

How important is degradation of the land resource economically?:

There is an enormous philosophical gap between the school of ecologists and anthropologists whose main interest seems to be in the preservation of the traditional ways of life and methods of land use of primitive peoples and natural ecosystems, against the inroads of technological change and intensive agriculture (which are seen as bad economically and socially); and the technocrats who see no real threat to sustainability in the world as a whole because technical change and capital investment have such a powerful influence on productivity that technical solutions will always be found.

Apart from tunnel vision on the part of protagonists of these two opposing views; the issue is obfuscated by the poverty of hard facts and data on the causes and magnitudes of various losses due to environmental deterioration, their economical and social value, and the costs and benefits of attempting to minimize them. The data that exist generally fail to distinguish between unavoidable losses, mainly from natural causes, and

avoidable or preventible losses from mismanagement. Sometimes the statistics are conflicting.

Definitions are often ambiguous; for example countries may put different interpretations on what they report to FAO as 'arable', 'fallow', 'permanent pasture', 'forest', and 'other' - including 'waste'. 'Irrigation' may include land supplied by highly efficient modern canal systems, tubewells, miscellaneous wells and lifting devices, or simply river flooding. Land quality usually cannot be assessed from such data, particulary with respect to natural rangelands and forests. In its AEZ studies, the A.T. 2000 report, and subsequent work with UNEP and IIASA on carrying capacity FAO has done much to try and define land suitability to key annual foodcrops; but there are yawning gaps with respect to actual and potential land use for other annual crops, perennial tree crops, pasture, and forests. Moreover the FAO studies deal only with developing countries.

The differences in various estimates of the potential land available for cultivation in the world are even more startling. Analysis of the conclusions of six global studies (Oram 1979), shows that the differences in their estimates exceed the entire 1975 area defined in the FAO Production yearbook as under actual arable farming (including permanent crops and sown pastures). Such a range is almost incredible in an age when remote sensing techniques should have provided the means for more precise definitions.

Other issues related to sustainability of land resources in which large estimates of dubious authenticity have been widely publicized include desertification, deforestation, and losses

from soil erosion. Some figures cited for the latter are mind-boggling, and might suggest that no soil will remain before long in large areas presently cultivated if current rates of loss continue unchecked.

There is a need for better cross-checking of these various assessments, so as to provide a proper base for future monitoring and evaluation of progress towards sustainability in land resource management. Unfortunately, reliable data are hard to come by, especially those with adequate cost estimates. Dregne (1986) states 'Measuring desertification costs requires a data collection operation that no public or private entity is prepared to undertake on a large scale', and 'There are not enough data to make anything like a reliable estimate of global desertification costs'. Dudal (1986) agrees. He states 'There are only very general estimates of the areas which are affected by degradation, of the rate of degradation, and of the losses of productivity which occur': The task of raising the precision of these estimates as well as putting statements such as '92 million tons of soil are lost annually from croplands in the six Western States of the United States', into an economic context, is clearly not a small one.

But if policy-makers, internationally or nationally, are to be expected to treat such losses seriously, and especially if they are to take costly and possibly unpopular action to reduce or control them; then they must be presented with hard, sober, unemotional facts relevant to the situation in their own jurisdiction. More research is needed to provide those facts, and to relate them to specific land use patterns and identified

eco-climatic or agricultural parameters. Where are the high-risk areas; what are the degrees of risk in adopting or encouraging various patterns of land-use and technology in such areas; how do the returns match the risks; what is worth conserving, protecting, or reclaiming, and what should be written off or mined to exhaustion, are the sort of questions which need to be answered. The CGIAR has not so far shown much interest in such issues. Perhaps it should do more ongoing work on agro-ecological characterisation; resource classification such as CIAT's pasture potential studies in defined zones of Latin America; soil research linked to economic evaluation to determine whether or not sustainable crop or agro-forestry systems are feasible in Amazonia; so as to provide entry points. Maybe more resources should be devoted to these critical issues and less to breeding programs.

Such research might also help to bridge the gap in information - if not in theology, between the more extreme schools of ecological and anthropological dogmatism on the one hand and technological stargrazing on the other.

Is rapid population growth a curse or a blessing?:

While rapid population increase is held by many authorities to be a root cause of poverty, environmental degradation, and declining levels of sustainability; others argue that the effects are not wholly bad, providing extra labour for poor families and acting as a stimulant to the adoption of more intensive methods of farming. There is, in fact, something in both of these viewpoints: the problem may not be the rate of population growth

per se, but what absolute level is sustainable over time within the bounds of reasonable expectations of technical change. The issue merits unprejudiced research; since it is highly charged with religious and other emotional content. The urgency lies in the fact that the difference between the high and median UN population growth projections for 2025 is equivalent to the entire 1980 population of India!

The strategy which needs to be adopted to prevent loss of the capacity to sustain a given level of population is likely to vary with land availability, irrigation potential, climate, employment capacity, income, health services, and nutrition. Why is fertility low among nomadic pastoral people in the Sahel and so high in Kenya? Many aspects of social, biological, economic, and medical research need to be undertaken in concert, and doctrinaire attitudes avoided.

What are the implications of autarkic food policies for future land use and sustainability?:

Sustainability in terms of food supply will be no problem for some countries, because of their capacity to produce sufficient from their own resources, without degrading their environment - Argentina and the United States are examples. But sustainability in terms of food security does not necessarily imply food self-sufficiency at any cost. Gaps in domestic production can be bridged by importing food paid for by export earnings from industry and/or agriculture. In the case of agriculture, which is the main source of foreign exchange for developing countries, adverse terms of trade imposed largely by

developed country importers, are exacerbating their difficulties in maintaining food security through trade, and thus threatening ecological sustainability by forcing them to try and grow more food with inadequate inputs due to shortage of foreign exchange, and in agro-ecological zones to which probably other commodities may be better suited.

This may be seen as a blessing in disguise by the 'Food First' school of thought, which holds production of 'cash crops' to be bad; (presumably meaning non-food crop, since pure subsistence outside the cash economy is relatively rare). However, ecological comparative advantage in the tropics usually also reflects economic comparative advantage, and, particularly in the wetter areas, forests, tree crops or perhaps agro-forestry systems, rather than annual food crops or grazing are probably the logical form of land use. It has been suggested that cash crop production decreases food security, and reduces expenditure on food in favor of consumer goods. This is an area of research with important implications for CGIAR on which IFPRI has already undertaken several studies in cooperation with African countries. So far the conclusions do not support the thesis that production of non-food or food crops for domestic and/or export cash sale is detrimental either to family incomes or to family nutrition. More research in other regions - particularly Latin America is desirable on this issue.

What are the effects of unequal access to land on sustainability?:

Both among and within countries the size distribution of land holdings varies widely, and this is only partly related to the climate, the quality, or the location of the land. Generally holdings tend to be larger in highly variable or marginal climates, and areas of poorer soils; as well as in 'frontier' areas where land-grabbing may be easier. In mountains and irrigated areas of developing countries, or in very fertile areas, they may be smaller. But this is not invariable; history, inheritance, wealth, and influence play a big role.

Many farmers are not owner-occupiers but tenants; and tenancy laws, rents, shares of costs and benefits with landlords, security of tenure - and thus incentives to sustainable management rather than land mining, vary greatly. The location as well as the size of a holding, whether owned or tenanted, in relation to climate, soil quality, water (especially for irrigation), roads and markets, critically determines both land values and how and for what purposes sustained production can be achieved.

Should priority be given to developing areas of high yield potential, or finding solutions to increasing output from resource-poor areas?

Given the inequalities and constraints imposed by farm size, location, and tenurial rights, a difficult issue is whether to concentrate research and investment policies on the more 'favorable' areas (ecologically) and the more 'progressive'

farmers; or to assume that they are better able to look after themselves, and to focus more resources on alleviating the problems of 'resource-poor' farmers (or areas) and the 'poorest of the poor' IFPRI's Africa research suggests that the latter might benefit women who tend to be progressively shut out as managers of holdings in the better areas. Nevertheless, development strategists (including the IIASA publication entitled 'Food for All in a Sustainable World'), seem to argue increasingly in favour of the high potential areas. So does Dregne in defining priorities for action to prevent desertification.

This, however, is an argument for efficiency, not necessarily for equity; and if the main threat to sustainability does not lie in the intensively farmed and stable environments, but in the more 'fragile' areas, including those grazings and forests on which cultivation is presently encroaching, it may ignore the roots of the problem. Nor, for similar reasons, would an efficiency strategy alleviate 'the tragedy of the commons', although it might lead to their elimination!

Another argument in favor of a selective focus on areas likely to give the greatest response to improved technology is that it simplifies the difficult task of providing inputs, infrastructure, and institutional backup to producers. Since this is one of the main obstacles to reducing inter-annual variability of yields and increasing productivity, and trained staff experienced in management is a limiting factor to more efficient institutional development, it makes sense to

concentrate such staff in areas where their presence is likely to give the largest impact.

This argument is difficult to refute in terms of efficiency, although it seems likely to polarize the gap between rich and poor areas (and probably rich and poor farmers too), even further. Evidence from Amazonia, the Philippines, the Sudan, and elsewhere, shows that as distance from the center increases, the difficulties and costs of obtaining title for land, capital, credit, and in dealing on all sorts of matters with bureaucrats, also increase, proportionately more for small operators than large ones.

Should some areas be monitored for sustainability. If so, how?:

A question mark must be placed against the value of a high technology potential area focus in learning more about the human and biotechnical factors determining sustainability, especially if deterioration is occurring largely in more marginal or remote areas, some of which may not yet be fully developed for agriculture. Admittedly monitoring sustainability is easier in a more restricted and accessible area; but it might miss dangerous externalities threatening that area (silting of dams, etc.) due to loss of sustainability in more vulnerable areas upstream, which were not being monitored. Little serious attention seems to have been focused on monitoring or evaluation of land use in relation to sustainability. It is an issue which merits more international or national cooperation, both for training and in its implementation.

How can local people help make policy:

Finally we return to the human factor, since many of the problems of sustainability relate to competition for resources between potential users with different and often conflicting objectives, as well as between individuals or communities and society. Common resources raise particularly difficult issues, since they are often in ecologically vulnerable areas (semi-arid grazings, mountain watersheds, rain forests), and in some - but not all cases, no-one feels responsible for the resource and everyone exploits it.

The inexorable expansion of cultivation is a second major problem. This is especially true where it is opportunistic; but even planned settlement schemes, in Indonesia and Tanzania, for example, have given rise to major problems of sustainabililty. Since arable expansion is bound to continue, and generally will extend into areas more remote and/or more marginal than much of the area presently cultivated, great problems of sustainable land management will have to be faced. Both in new lands and in common lands (particulary the latter), frictions have arisen in the past between government officials and agencies and those people wishing to use the land. This has been a particular problem in forests over which the State often claims some sort of lien: forest officers tend to be fiercely protective of their patrimony, and are not above using police or military to clear other people out.

If these conflicts are to be avoided in the future; and if, as many authorities urge, incentives are to be provided to people of an area to act responsibly for the common good in the use and

management of their resource; then elected local people must be given a chance to become involved in the planning and implementation of their own land use policy. This runs the risk of local persons of power and influence obtaining an unequal share of the cake; but it is probably better than having a top-down plan imposed by bureaucrats with little local knowledge and sympathy, and which would probably still fail to give greater equity to the disadvantaged. Moreover if institutional skills are in short supply, the more the cooperation and interest of the local people can be stimulated, the more chance of successful implementation.

'People involvement' in a land use plan, is an endeavor which requires inter-disciplinary cooperation, and which seems not to have had the attention it merits from researchers. In some ways it is closely allied to analysis of agricultural systems such as inter-cropping, agro-forestry and crop-livestock integration, but since several systems of land use may co-exist in a study area, it requires a more holistic view of the climate, natural, and human resources of the area. Concepts of agro-ecological zonation, recommendation domains, and analysis of spatial comparative advantage, possibly using Domestic Resource Cost criteria, may be useful planning tools.

What questions need to be covered in formulating land use plans?

As a basis for policy decisions as to what action to take to ensure sustainability, it is necessary to be able to place land use and land degradation in the context of a specific cause-and-effect situation; to understand more about the direct and indirect losses in financial and social terms, to quantify

the potential benefits and costs (economic and social) of preventing such losses in future, and the time required for remedial measures to be effective; and to identify the extent location, and severity of the areas most under threat.

Since it is quite likely, especially in more environmentally diverse countries, that there is more than one type of threat to sustainability of the land resource, it may be necessary to collect and analyze data of the kind described above on each as a means of determining priorities for action. For example, deforestation of watersheds due to encroachment of cultivation on closed forests; desertification due to overgrazing of semi-arid regions; and wind erosion due to improper use of mechanical tillage equipment, may all be going on in parallel in a country. The policies required to prevent or reduce further losses from these different causes are not usually the same. Some may extend beyond the boundaries of the agricultural sector. Which should receive priority? Such issues can really only be resolved by survey and research at the national and local level, requiring close collaboration between scientists in several disciplines, and directed to the formulation of a national land use plan designed to achieve stated social and economic goals over a sustained period of years.

Among questions which require to be answered in developing such a plan are:

- The location and extent of the main agro-ecological zones.
- The nature of current land use in each zone.
- Current levels of technology and crop and livestock yields in each zone.

- Assessment of land capability and any measures required to halt and reverse downward trends in sustainability of the resource base, both in the short- and longer-term.
- Potential for a sustainable increase in productivity in each zone through changes in land use patterns, cultural practises and levels of technology on specified assumptions of cost, employment, and population-support capacity (including humans and livestock).
- Reasons for differences between actual and potential land use: economic, social or technical.
- Identification of priority objectives for action.
- Social or other non-technical measures required to make the proposed changes feasible.
- Investment costs to achieve the planned objectives.
- Further research required to help in planning or implementation.

A central objective of such plans should be to identify and classify:

- High potential areas suited to intensive agriculture, and possibly capable of supporting a larger population as a result of specified policies and investments.
- Stabilisation areas, where agriculture can be practised with appropriate safeguards against degradation, but where limits should be placed on movement of additional people into the area, and where land use and incentive policies should encourage conservative rather than intensive production.

- Conservation areas, which may not be suited to any form of cultivation and where grazing or fuel-gathering may need to be limited and monitored. Parts of such areas might be used as game reserves or for other public recreational purposes; Parts might be closed to intrusion or use other than by their indigenous inhabitants. This would apply especially to areas whose degradation threatened more fertile lands. Some might have a potential for reclamation, especially if this would enable them to be used more intensively - perhaps under irrigation or as managed forests. Generally, however, land in this category would not be expected to yield a high return to capital investments, although action to prevent hazardous externalities might justify some expenditures.

PART 4

Policies to enhance the contribution of technology to sustainability. Successes and failures:

1. Crop production.

Technology has contributed to triumphs and to failures in sustainability. Among its greatest achievements have been the continuing long-term increases in output of grain, meat, and milk in Western Europe and North America, which has been a major factor in increasing world cereal production from 700 million tons in 1950 to 1,800 million tons in 1985, tripling meat production and almost doubling milk production in Europe over the same period, despite the extremely high man:land ratios there. The seed-fertilizer "revolution" in Asia has enabled countries such as India, written off as unsalvageable by the proponents of Triage, to increase productivity per unit area substantially, although generally in rather more favorable terrain for irrigated agriculture than in Africa. Most of the successes in these regions have been achieved by raising yields, with increasing inputs of capital both for fixed assets and recurrent cash inputs.

By contrast, yield-increasing technology has been much less successful in increasing productivity of land and water resources in Africa and some parts of Latin America, while in Sub-Saharan Africa labor productivity is also very low. Input use in many African countries, especially for food production, is negligible. Binswanger (1986) argues that this is because many African countries are still relatively land abundant, and that in those

circumstances they are more likely to be interested in new crops, cultivars or innovations which produce a higher return for a lower labor input than they are in fertilizers, irrigation, or soil conservation. He reinforces this argument by historical analogies with the adoption of yield-increasing innovations over time in Asia. His conclusion is that demand for land-saving research of the type which led to the "Green Revolution" in Asia, and support for experiment station funding generally, will be hard to stimulate in Africa, except where land is becoming scarce. Stress tolerance, disease/pest resistance and enhancement of quality are the objectives he advocates for most areas of Sub-Saharan Africa.

Although these arguments are persuasive, they do not account for the generally low levels of fertilizer use, even in the less-land-abundant areas of Africa, nor for the apparent failure of African farmers to adopt animal traction, herbicides, or other labor-saving techniques. Moreover, if the ability to cultivate and plant all the land available by hand in timely fashion in rainfed areas is a main limiting factor to higher labor productivity, the reduction in area needed to produce an equivalent quantity with more intensive methods could be an incentive to adopt them. His argument concerning producers' lack of incentives to replant or to take other measures to raise tree crop yields in Africa is unconvincing in view of the success of tree crops in the Ivory Coast, where improved crop technology has played a leading role and the relative failures in Ghana and Nigeria, where it has not, and which have lost their respective pre-eminence in cocoa and oil palm as a result.

However, the constraints imposed on the ability or willingness of producers to adopt new methods by weak research systems and other technology-supporting institutions, political instability, inefficient and corrupt marketing boards, penal taxation of export crops, and subsidized cheap food imports, introduce a set of uncertainties into the whole question of what crop technology is applicable to various ecological and social situations in the rainfed tropics, whether any currently exists, except in a few limited situations, and mainly for export crops, and which policy incentives are most needed to stimulate its use. There has been a progressive decline in per capita grain production in 20 African countries over the last 30 years, as well as in 9 Central and South American countries. These countries embrace a wide ecological spectrum and are not mainly located in climatically marginal areas; nor are they all land-scarce countries. This suggests that technological problems are being compounded by other factors, of which political instability is clearly one. We will return to these problems later.

2. Animal Production

Much less uncertainty clouds the verdict on the success or failure of ruminant livestock management in the semi-arid regions of Africa north and south of the Sahara, as well as in parts of Asia. Generally ex post evaluations by experienced livestock specialists who have worked for considerable periods in range areas of Africa (Gow, Dregne, Oram, Talbot) are unanimous that not only has technology failed to prevent overgrazing and degradation of rangelands, it has actually exacerbated it. Moreover, a vast area of the better-potential grasslands remains

infested with tse-tse fly, which limits its use and to which only partial solutions have been found.

A recent report on milk production in China (Gorissen and Vermeer 1985) states: In 1979 only about 10 percent of China's production came from grazing regions. The prairies and mountain grasslands produced 30-40 percent less hay than during the 1950s. According to a 1981 survey, a quarter of the pastures were salinized or covered with sand, a third lacked water, and another third was infested with rodents and insects. Of the 224 million hectares of usable pasture only 18 percent was of good quality. "Man-made" grassland was only 0.2 percent of the total area. Deserts in the northwestern region (which has 44 percent of the national pasture area) are growing by 700,000 hectares a year, and about 47 million hectares have been lost since 1950 by desertification or deterioration.

Nor have problems of improving ruminant livestock nutrition been solved in the wetter tropics of Asia. Some parts of Sri Lanka, Malaysia, Indonesia, and the Philippines are critically short of grazing lands; in others such as Sumatra, Mindanao, and northeast Thailand, where pressures on land are less, little success has been achieved in developing suitable grass-legume mixtures for grazing. Large areas in Indonesia, Malaysia, and the Philippines are infested with Imperator Cylindrica a pernicious weed.

3. Forestry and fuelwood production

While there has been considerable technological progress in forest inventory, silviculture, and timber extraction, this has not prevented an increasing decline in the

area under forest, and may have contributed to it. If timber is extracted by methods which do not lead to soil erosion, and land from which timber is extracted is replanted and properly managed, there should be no cause for concern. However, as mentioned earlier, this often not the case, and when land previously under forest is abandoned to cultivation or grazing, rapid depletion of the resource base usually follows.

This is one major problem. However, it can be attributed more to greed on the part of the timber producers and failure to develop cultivation and grazing management practices appropriate to cleared forest land than to lack of technical competence in forestry itself. The second major problem is how to provide fuel to meet the needs of a growing population, not only in rural areas, but also in cities. At present, wood is the main source of supply, and demand is increasing in urban areas, especially in Africa. This provides cash income to rural wood gatherers, whose own demands are also rising. An FAO survey shows that areas being cleared exceed those deliberately planted in Africa by a ratio of 29:1. Trees and shrubs are also a source of shade and fodder, especially for ruminant livestock: thus there is competition for their use which accelerates their destruction. No satisfactory and economically viable solution has yet been found to replacing this lost resource, either through replanting or through substitution of wood by other energy sources.

Thus major challenges exist to finding technological solutions to key problems of resource depletion; which cast doubts on the long-term sustainability of agriculture in substantial areas of the world. This reinforces the case for

concentrating short-run efforts in high potential areas for which suitable technological fixes are available, but it requires some difficult policy decisions as to how best to combine rapid progress in those areas with improved management in resource-poor regions.

In considering these issues, it is necessary to clear one's mind of cant. Some current writings on technology seem to imply that chemical and mechanical technology are "bad," and biological technology and "appropriate" technology are good. "Appropriate" is usually confused with small; "small is beautiful" sometimes but if it does not fit the situation in which it is being used, or if it is being misused, a "small" technology may be as inappropriate as a large one. However, the scale of the resulting problem may be smaller.

The experiences cited above do not suggest that one component of technology is universally desirable or undesirable, dispensable or indispensible. Often they interact synergistically. Some are more neutral to scale and less capital-intensive than others; therefore they may be better suited to small farms in developing countries. But that does not make other types of technology wrong where they can be used efficiently.

The most destabilizing environmental effects yet recorded have largely occurred in circumstances where no technology has proved very effective - rangelands, fuel-wood gathering, and in ancient canal irrigation systems designed without adequate drainage or good water storage facilities. The challenge is to find solutions to the problems impeding sustainability, whether

those solutions are technical, institutional, social, or some combination of approaches. Preconceived notions of what constitutes good or bad technology may simply retard progress.

A wide range of issues is involved, of which appear particularly critical:

(1) How can fertilizer use be increased, especially in higher potential areas?

There is a unanimity on the need to step up the trend growth rate of agricultural production in the developing world. It is also clear that such acceleration requires continuous increases in yields per unit of land and time. Much of this increased production will be sold off the farm; thus fertility is being exported at a progressively higher rate and nutrients must be replenished if yields are not to decline. Stored fertility in newly cultivated land can be mined for a few years, but once it is exhausted it can only be restored by the addition of chemical fertilizer, and/or organic manure. Ideally, both an adequate nutrient status and a good organic matter content is needed to improve physical structure and water holding capacity as well as providing nutrients. Both chemical fertilizer and organic sources of nutrients have a role to play in achieving this balance. A problem with the latter is that animal manures are relatively low in nutrients in relation to their volume, and are widely used for fuel in some countries; while green manuring is rarely economic.

Thus, a vast increase in the use of chemical fertilizers is generally considered essential to generate and sustain yield-based growth in agriculture. According to FAO's AT 2000 study,

fertilizer consumption in the developing world (excluding China) needs to be raised from about 13.5 million metric tons (mmts) in the mid 1970s to about 94.4 mmts (in Scenario A) and 75.6 mmts (in Scenario B) by the year 2000). This implies an average annual increment of about 3.2 mmts in Scenario A and 2.5 mmts in Scenario B. Against this, so far, consumption in the developing world (excluding China) has increased by about 1.3 mmts per year. Worse still, growth in consumption has been most sluggish in a number of countries where it is most urgently required, especially in Africa.[2] Thus, the real question concerning fertilizers in discussing sustainability of agriculture in the developing world is not <u>whether</u> but <u>how</u> to step up growth in consumption.

This cannot be over-emphasized. While discussing fertilizer-related issues, one often hears about the high cost of chemical fertilizers, their adverse environmental impact, and hence the need to follow alternative approaches like organic manures, BNF technology, and alley cropping. But a careful examination of these considerations and their potential for helping to maintain soil fertility in different agro-ecological zones suggests that they do not establish a case against raising fertilizer use in the developing world. What they do establish,

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2 For example, World Bank data for Kenya (a country where considerable efforts have been made) estimate that the gap in fertilizer use between recommended and actual rates of application was 150,000 tons of fertilizers (100,000 tons for maize; 50,000 tons for tea and coffee, key export crops), which is nearly equivalent to Kenya's current fertilizer consumption.

however, is that they merit prudent attention in evolving fertilizer policies.

For example, ability to maintain soil fertility economically by fertilizer use alone in the wetter tropics, especially in land cleared for food crops in areas previously under forest, is an issue which is not yet fully resolved. However, studies in South America by Sanchez and Nicholaides suggest that this is feasible. Tshibaka states that crop yields in the forest region of Ghana have been maintained for almost 20 years in continuously cultivated land by modest applications of mineral fertilizer. FAO trials on food crops in a wide range of ecological regions of Africa result, overall, in substantial responses to fertilizer. Yet it seems probable that, especially in the less arid areas, a combination of chemical fertilizer with the use of leguminous trees or shrubs in alley cropping or agroforestry systems may provide the best solution, but much more needs to be learnt about the optimum balance of perennial and annual species, spacings, cultural techniques, and mineral and organic nutrients. This is an important area of research.

The environmental hazards of using chemical fertilizers are real, but only at the very high rates of application attained in some of the developed countries. In the developing world a very high proportion of cropland is either not receiving any application of chemical fertilizers or is fertilized at very low rates. Hence, what is required are policies to build institutions and ethos to monitor and promote judicious use of fertilizers.

One other contribution of fertilizer to sustainability that appears to have received little attention is its effect on labor use and productivity, at least in Africa. A trial conducted in Yangambi, Zaire shows that a technically optimum application of 400 kilograms of NPK per hectare increased the labor employment by about 50 percent and the average product or productivity of labor in cassava production by 22 percent. IFPRI research in Zambia shows that the effect of fertilizer use in raising the labor productivity of smallholder food producers is striking. Conclusively, if properly used, fertilizers can stabilize farm yields and increase land and labor productivities. Fertilizer use can also influence farm labor use positively.

Although the growth rates of fertilizer use are somewhat higher in other developing regions than they are in Africa, in no region does the average level of NPK consumption per cultivated hectare yet approach the goals suggested in FAO's AT 2000 study. Yet if these goals are not attained, many more countries will be unable to feed their populations adequately by the year 2000, and either imports will have to increase or more people will be malnourished. Thus the design of an appropriate fertilizer policy framework is a crucial task, not only in countries which are land scarce, but also in those which have scope for bringing new land under cultivation, to counter rapid depletion of its fertility.

While the priorities will vary among countries, the common objectives which need to be taken into account in designing fertilizer policy are to:

1) increase fertilizer use by crops;

2) reduce and eliminate the gap between recommended and actual rates of fertilizer application;
3) accelerate the rate at which new lands are fertilized;
4) increase the diffusion of fertilizer on small-scale farms and low potential areas;
5) improve farmers' technical skills; and
6) increase the economic potential of fertilizer use.

Currently, the ability of policymakers to devise this framework is often constrained by a lack of knowledge about how key policies influence the supply and demand of fertilizer and other technology carrying inputs. This requires research to identify the key variables and their impact.

Research-based policies in five directions are required: (i) those which lower farmers' cost of fertilizers through removing numerous deficiencies in fertilizer production, imports and distribution, as well as agricultural credit systems to help both in distribution, and purchase by farmers, (ii) those which identify and facilitate the use of natural fertilizer sources in developing countries: rock phosphate, gypsum, guano, etc., (iii) those which improve responses of crops to fertilizer use and improve efficiency of use by strengthening agricultural research and extension systems and the interface between them, (iv) those which develop efficient agricultural marketing and processing systems and thus raise farmers' share in consumers' price of their produce, (v) studies of appropriate fertilizer pricing

policies in relation to their delivered cost and producer returns in output valued at market prices.

Rapid growth in fertilizer use cannot be sustained without these policies. Agricultural subsidies (either on inputs or outputs) are not a sustainable solution in the developing world. In fact, they usually distract attention of the policy makers from the more demanding tasks of developing systems which are indispensable to viable growth in fertilizer use. Worse still, by constraining fiscal resources, such policies often restrict public expenditure on the development of external economies which play a crucial role in transforming traditional agriculture into technologically dynamic agriculture.

As for organic manure, BNF technology and practices like alley cropping, it seems sensible to view them not as effective alternatives but as important complements to chemical fertilizers, at least in the foreseeable future. Although this is seldom disputed, it needs repeated reiteration because it is often forgotten in discussing fertilizer related issues of the developing world.

Thus, a new orientation is needed on fertilizer-related issues when discussing sustainability of agriculture in the developing world. This orientation must be based on (a) a connotation of the term "sustainability" which recognizes the need for accelerated <u>but</u> cost-effective growth in agricultural production, and (b) a realistic understanding that fertilizer is indispensible to generating yield-based growth in agricultural production at the present stage of our technological know-how on meeting increasing requirements of plant nutrients. Without such

an orientation, the discussion on fertilizer issues can be counter-productive by distracting attention from many complexities and dilemmas which policy makers face in the developing world.

(2) What should be the place of mechanization and chemical tillage and weed control practices in sustaining agricultural production?

Mechanical technology, especially for tillage and harvesting purposes has contributed greatly to the expansion of agricultural output in developed countries; mainly through increasing labor productivity, but also to some extent in raising yields. The latter is probably attributable to the increasing versatility of machinery designed for row-crop cultivation, irrigation, weed and pest control, which has enabled a much wider range of complementary operations to be undertaken in a timely fashion. Scaled-down tractors, and particularly power lift toolbars, have permitted operations to be undertaken on much smaller fields, so that mechanization has spread to areas where holdings are relatively small, for example in European countries where land is no longer abundant. Thus, in those countries, it has become to an increasing extent a land as well as a labor-saving input.

Its place in the agriculture of the developing countries has been far more controversial. In East Asia, small-scale mechanization of rice production and harvesting has made considerable strides; and medium-sized tractors and harvesters have been used successfully in drier areas of India, Pakistan, Turkey, North Africa, and Latin America, mainly in the sub-

tropics. Tractors and trailers of all sizes are used extensively for marketing produce and other transport needs. Extensive mechanization of a range of operations has occurred in the Brazilian sub-tropics. In Sub-Saharan Africa, however, attempts at introducing tractors, mainly for tillage, have not been very successful - possibly because they were often part of state farms or other ambitious but poorly managed State enterprises; nor has mechanization been uniformly successful in South Asia, including Custom Hire services which proved uneconomic for many reasons.

Part of the problem has been that machines designed for use in North America or Europe have not proved suited to tropical soils and conditions; part that spare parts or foreign exchange for them has not been available; part that service centers were inadequate or non-existent and inexperienced operators were unable to cope with maintenance. The high cost of capital has been compounded in many countries by rising fuel prices.

From the point of view of sustainability, the problem is not simply one of poor operating and maintenance techniques leading to high running costs and machinery "graveyards," but of learning how and when to till and cultivate crops to prevent excessive runoff and loss of structure. There is a difficult research task in devising and testing conservation practices as well as in finding the optimum combinations of power (whether draft or mechanical) and equipment for specific operations, soils, and seasons. This is exemplified by ICRISAT's Soil Management Studies in India. Even when successful techniques have been worked out, there are equipment costs which may make them difficult for small farmers to adopt; and they may require

farmers to cooperate, as in watershed management. The step from a successful research result to adoption may, therefore, be large. In addition, there are controversial side-effects of mechanization on employment, equity of access, opportunity costs of capital and especially of foreign exchange, which go beyond its impact on the sustainability of the land resource.[3]

Attempts to introduce draft animals into Africa as an alternative to tractors has not been very successful; for one reason there is no tradition of ox cultivation as there is in Asia, nor of cultivated fodder production; while tse-tse fly has limited the use of draft animals in the wetter areas. Small, mechanical cultivators, while successful in level paddy areas of Asia, have not been effective in the dry and difficult soils of much of Africa.

An alternative to the wider use of mechanization to increase labor productivity and prevent soil erosion in tropical Africa and Latin America may be the use of various "no-tillage" techniques for soil preparation, and herbicides for weed control. The former seems promising experimentally; and in view of the effectiveness of herbicides it is surprising that they are not used more. Both are relatively neutral to scale and capital requirements for application equipment and chemicals are lower than those for mechanization. However, lack of knowledge and information on the techniques, unavailability of appropriate

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3 Empirical evidence, particularly with respect to the influence of mechanization on labor requirements, as well as on increasing crop yields, is quite conflicting. For example, two studies undertaken on effects in the Punjab (one in India, the other in Pakistan) reach very different conclusions.

formulations, and risks of mammalian toxicity may be impediments to their wider use to supplement human labor. Moreover, the utility of tractors as transport vehicles should not be overlooked. Inter-cropping practices may be a further obstacle to use of chemical alternatives. Long-term dangers of soil and water pollution have yet to be conclusively demonstrated, but should be carefully monitored.

Much research remains to be undertaken on the many technical, economic, and social issues involved, as a basis for sound policies for supplementing human labor in agriculture. Among these issues, the impact of the various alternatives on peak period employment for weeding and harvesting, especially of women and landless laborers, needs to be studied carefully. Conversely, the possibilities of releasing family labor at non-peak periods for off-farm employment should also not be overlooked. Overall this is a subject which merits very high priority in research on policies for sustainability. We wonder if it is receiving sufficient attention.

(3) <u>What technology is sustainable in "resource-poor" areas</u>?

A good deal has been written in recent years concerning the need for low-cost and/or low-input technologies which will enable production to be maintained and possibly increased without environmental degradation in areas unsuited to intensive agriculture. Sometimes it seems to be implied that such an approach should be adopted as a general strategy for small farmers in developing countries, although long-term, trend-

based projects of demand and supply suggest that the result would be large and probably unmanageable food gaps.

It is, in fact, quite difficult to do more than suggest some broad policy guidelines on this issue, since the actual approach will need to be varied to meet specific agro-ecological and socio-economic circumstances, including land tenure systems, distance from markets, and topography. Essentially the same principles of sound management apply to high potential and to less fertile areas; however returns to capital are likely to be lower in the latter, and risk and uncertainty greater. Thus, large expenditures on soil conservation and land reclamation measures or high use of cash inputs are probably going to be unrewarding, and expenditures on biological technology more rewarding. This implies:

i. That plant breeding should be directed to stress tolerance and yield stability, rather than to high-yield potential based on high nitrogen response and chemical pest, disease, and weed control.

ii. That integrated approaches should be adopted to pest and disease control including breeding for resistance, biological predators, cultural manipulation to avoid peak risk periods, complementary limited use of chemicals, and early warning systems.

iii. That soil fertility and structure should also be maintained as far as possible by careful selection of cultivars tolerant of adverse

soil constraints (acidity, salinity, toxic elements) and by developing complementarities between species (intercropping, alley cropping, use of fodder legumes in rotation with cereals); use of organic manures, such as algae; fallowing; and selective use of chemical fertilizer, especially phosphate, on nitrogen-fixing legumes.

iv. Mixtures of crops of different heights, morphological and phenological character, and rooting systems (trees, shrubs, perennials, annuals) to achieve maximum use of light, water and soil nutrients. Some protection against pests and diseases and insurance against climatic variability may also be achieved this way.

v. Introduction of stall-fed or tethered livestock and trees for fodder and fuelwood, as well as conventional fodder crops into farming systems.

vi. Use of labor in slack periods (if any) to undertake terracing, bunding, or other soil and water conservation measures.

It should be emphasized that some of these principles are also applicable to high-potential areas; also, that not all of them apply to all ecological zones. It is probably easier to adopt diversified farming systems in areas where neither rainfall nor temperature are severely limiting. Also, some of the measures

suggested are quite labor-intensive and may be difficult to follow where labor is scarce or expensive. Finally, although many of these principles are rooted in tradition, some of the concepts are novel and their success will depend significantly on good communications between farmers and research and extension staff as well as on flexible and accessible services supplying seed, plants, and biological control requisites. If anything, these integrated approaches may be more demanding on such services than the more conventional input supply requirements for high-yield technologies, especially where the latter are being applied to cropping systems dominated by a few key crops such as rice, wheat, or cotton largely grown as monocultures.

(4) Has relative variability increased as a result of yield-increasing technology?

This issue has been raised by Barker and Herdt, Mehra (with respect to India) and Hazell, and was the subject of a conference sponsored by IFPRI in 1986. As production increases the absolute size of inter-annual deviations from the norm due to weather and other factors may be expected to rise, but if relative variability also rises due to technological factors this could have serious repercussions on food security by destabilizing world prices.

Evidence presented by the authors cited above seems to point to an increase in coefficients of variability of crop yields in several countries, which could be attributed to technological change rather than simply to weather. These results were obtained mainly in Asia, Europe, the USSR, and the United States, rather than elsewhere: in any case they are unlikely yet to have

a significant influence on yields in Sub-Saharan Africa, because modern inputs and high-yielding varieties are hardly used there, and irrigated area is very small.

Three main influences seem to be at work. These are:

i. Use of related varieties with a narrow genetic base over large areas, thus increasing susceptibility to pests and diseases, and increasing the chances of inter-correlated effects in different countries.

ii. Fluctuations in input delivery systems and availability due to bureaucratic ineptitude, poor transportation facilities, foreign exchange constraints, and weather (especially for irrigation systems).

iii. Incorrect or unbalanced use of inputs by producers due to lack of experience and weak extension and information systems.

It seems from papers presented at the meeting referred to above that imperfections in breeding strategies, compounded in some cases by inadequate seed production and distribution systems have been a major factor contributing to technological yield variability, and in some cases to interactions between technology and weather variability. Variability due to these causes has been greater with some crops, e.g., with maize in the United States and hybrid millet in India.

However, several studies, some of which used longer time-series than the earlier papers, suggest that variability caused

by factors affecting input supply and use by producers, tends to decrease with time as experience is gained and mistakes ironed out by both suppliers and users. Finally, there is some evidence, for example from the USSR, India, China, and the USA, that relative variability at the national scale is lower in large countries because both adverse weather and some of the technical problems contributing to increased variability at the local level rarely occur at the same time across the country as a whole.

Nevertheless, there are important lessons to be learnt from these studies with respect to research policy, the dangers of the large seed-chemical companies dominating breeding programs, and the crucial role of efficient input supply and information services in the successful adoption by producers of new technological approaches.

(5) What can be done to prevent the deterioration of grazing resources in semi-arid areas?

This is a most difficult issue, as will be clear from our earlier observations. Many attempts have been made to find solutions, including major, costly and generally unsuccessful range management programs; control of animal numbers at some theoretical level of carrying capacity supported by measures such as government fodder reserves to stabilize weather variability; ranching schemes to improve grazing control and management; feedlots to absorb surplus stock beyond those needed to maintain range-fed breeding herds; and various market and price incentive schemes with a similar aim in view. Large sums have been spent on well drilling and other services intended to give graziers access to a more extensive radius of pasture. None

has proved generally successful, and in desperation some governments have tried draconian measures to control movements of people and animals, including resettlement of nomadic herdsmen as sedentary farmers in irrigation or other government-supported schemes. These also have poor success records.

What can be done to rectify this increasingly desperate situation? A study by McClintock (1983) showed increases in physical livestock output to be associated with increases in animal numbers rather than to technical change; no significant associations were detected between growth and research or veterinary expenditures, domestic investment, or infrastructural investment. Human population is increasing among pastoral peoples, albeit more slowly than in urban and settled farming areas; and animal numbers, although with large weather-related, inter-annual variations, have tended to increase at approximately the same rate as their owners.

A first essential seems to be to understand more about the actors on the scene. These include first and foremost the pastoralists and their animals; secondly the cultivators and their linkages with the herders; third fuel-gatherers; and finally the various government and other agencies trying to find ways of solving the inter-acting problems of the various people involved. One reason cited by several African experts for the failure of so many government and technical assistance efforts is a tendency to try and apply solutions which have worked elsewhere (especially in Western countries) to African problems, without adequate knowledge, experience, or time-series data. This seems to justify the rationale for ILCA spending a substantial

proportion of its time and resources on studying the traditional livestock management systems of Africa, the attempts that have been made to improve them, and the reasons for their failure, rather than following classical animal breeding and veterinary approaches.

A perplexing question relates to the degree of control which governments attempt to exercise over movements of people. If, as is frequently stated, encroachment of cultivation into grazing areas causes a chain reaction leading to loss of sustainability throughout the land use system, then that ought to be stopped. If over-grazing is increasing, some of the animals ought to be removed and movement restricted. If firewood-gathering is compounding deterioration of the environment, that too ought to be regulated. This raises difficult issues of policies and priorities, since all of these people are very poor and it seems doubtful if taxes, grazing fees, fuel-gathering licenses, or rents on grants of land expropriated by the State could be imposed or even collected physically. Cultivators greatly outnumber herders in semi-arid areas, but the pastoral peoples are probably more vulnerable to climatic hazards, as statistics concerning famine deaths and livestock losses indicate. Both settled people and nomads depend heavily on natural vegetation for fuel. Action to promote cooperation seems more likely to succeed than coercion.

In the long term it is to be hoped that technological progress in cultivated areas will reduce the encroachment of farming into grazing areas; but technological progress in the latter is minimal. The returns to trying to reclaim severely

degraded pasture by reseeding or other direct technical measures are low and slow-maturing: policies should therefore be directed towards decreasing grazing pressures at critical periods of plant growth to encourage natural regeneration.

This policy recognizes that the range, when properly managed, represents a large potential reservoir of ruminant animals. When put on to a better feeding regime (whether on improved grazings or in association with fodder production) these animals can gain weight fast without having to improve the breed: No "high technology" is involved -- only better feeding and management. This potential has led ILCA to suggest that more attention in research should be directed to developing technology for ruminant fattening in sub-humid areas, even though there are much larger absolute numbers of animals in semi-arid rangelands, as a way of reducing pressure on the latter. How can this reservoir best be tapped?

A first measure would be to help restore the nutritive value of natural grazings by controlling range water points and restricting cultivation in erodible low rainfall areas. The latter is particularly important (apart from being a prime cause of erosion) because reestablishment of natural vegetation on land that has been plowed is a lengthy process.

Second, it is important to foster, and perhaps to subsidize, accepted systems of voluntary grazing control within traditional tribal boundaries or village common lands. In many countries these have been legally abolished in favor of state ownership of land, but because this can rarely be properly enforced, the result has been uncontrolled, free-for-all grazing. It is

essential to work with the local people in efforts to protect, conserve, and manage communal resources. The formation of grazing cooperatives along the lines of the Hema system in the Near East is one possible solution.

Third, means must be found to provide more stable outlets from the range for immature animals, surplus to the needs of maintaining range breeding herds, so as to reduce their mass slaughter at low weight when the natural vegetation dries up, and to permit destocking of the range at critical periods of pasture regeneration. Fattening cooperatives in irrigated areas, feed lots, the introduction of leguminous fodder crops into the dryland cereal system in place of fallow for grazing (possibly on a subsidized basis initially), improved marketing channels, and prices giving incentives to better finish of animals are some of the "downstream" measures necessary to provide this stability. Kenya has made considerable progress along these lines; so have some West African countries. However, isolated measures have often failed; a carefully orchestrated and integrated strategy is required, with strong support to private initiatives.

A fourth measure must be to expand research on ruminant livestock production in settled farming systems in better rainfall areas, where the scope for fodder crops or grassland management with fertilizer and improved species is greater. Some of the best of the potentially productive savanna areas in Africa are currently protected from mis-management by the tse-tse fly, but eventually will become available for crops and livestock. It is urgent that systems which integrate crops and livestock in such areas are developed and tested for their management, if a

dangerous collision between herdsmen and cultivators is to be avoided once the disease problem is under control.

Pressures on the ruminant livestock sector in Africa and especially on the range are being accelerated by population growth, human and veterinary health measures, new means of cross-country transport, mobile well-drilling outfits, and by escalating demand for meat and milk. Yet social structures, land holding and grazing rights, grazing management practices, technical and, particularly social research; and, in most cases, government recognition and willingness to take any action to effect improvements are lagging behind the pace of events. Efforts should be made to control and regulate land use, but since these may require sacrifices from both farmers and herdsmen, they should be accompanied by equally vigorous support to producers in research, technical services, finance, marketing and transportation.

The aim of ruminant livestock policy should be to promote conjunctions of interest between settled farming, herding, and planting of trees for fuel and fodder, rather than the destructive competition that has so often been the rule in the past because the externalities rather than the complementarities have been dominant. Current trends in Africa urgently need monitoring since they contain the seeds both of hope and potential disaster.

National policies are required to reconcile these potential conflicts, and in most countries these imply a drastic rethinking of support to the livestock sector commensurate with its social and economic potential.

PART 5

Sustainability in Irrigated Agriculture

Introduction

i) Key problem areas

In moving from more general consideration of the notion of "sustainability" in agricultural systems to its application to a particular sub-sector, we can be more specific about both the nature of the issues and the shape of possible solutions. Three broad problem areas come quickly to mind when we think about the "sustainability" of irrigated agriculture, or of an irrigation system.

The first of these relates to the central role that irrigation development has played in increasing agricultural output in a large number of developed and developing countries. Examples as diverse as the United States, India, Pakistan, the Philippines, Egypt, Syria, Zimbabwe and Nepal can be mentioned. The importance of irrigation in realizing the productive potential inherent in improved wheat and rice varieties--both through its direct yield and cropping index effects and through its interaction with fertilizer application rates--is well known. The sustainability of past rates of growth in production and productivity in the face of an anticipated decline in the rate of new system construction, particularly in Asia, is thus a question of considerable importance.

Second is the issue of the sustainability of the functioning of the irrigation systems themselves. A number of recent studies and evaluations have highlighted problems of shortfalls in area served by irrigation systems, poorer than expected productivity, allocational disparities between head and tail-enders, large recurrent cost burdens on government, overrapid system deterioration and the need for frequent system rehabilitation. Sustainability in this sense is an issue that profoundly affects not only the viability and productivity of existing systems but the economic rationale for the development of new irrigation command as well.

A third set of issues relates to the short- and longer-term interactions of irrigation schemes with their (physical and human) environments. Included here are the impacts of related systems such as livestock and agroforestry systems in upper watersheds on irrigated agriculture downstream, as well as the negative externalities of irrigation development and operation themselves on populations and resource bases. Both types of effects degrade physical resources that are clearly finite in extent, require complex socio-technical approaches for their resolution, and represent problems that have so far defied easy solution.

There are clearly strong interrelationships among these three sets of issues, and any approach which treats sustainability in the context of irrigated agriculture must take all three into account.

ii) Irrigation and Agricultural Growth

Until quite recently, Most growth in irrigated agricultural production has come through expansion of area irrigated. In Asia, this era is drawing to a close as the most accessible resources are exploited, and in Africa extremely high irrigation development costs similarly constrain creation of new capacity. However there remains scope for development of new command in both regions, although both face similar problems in justifying such development on economic grounds.

The second source of irrigation-related growth in production--more effective utilization of already-developed water sources--is somewhat more complicated. In some cases, it may be possible to augment existing supplies. Often, however, irrigation will have to make do with less water rather than more as competing users such as municipalities increase their higher-priority demands. This is already happening in places such as Tamil Nadu, Central Java, and the Western United States.

Irrigation systems will thus be called upon with increasing frequency to sustain growth in production with a fixed or even a declining water resource. Tools and mechanisms which blend (1) physical improvements, (2) changes in management structures and practices, and (3) policies governing the subsector are available to accomplish this, however results have been uneven. Although experiments applying differing combinations of these factors have

been undertaken, often in an "action research" mode, there is not yet a clear understanding of or agreement on the sets of measures which are most appropriate in particular settings, or on the magnitude of their impacts.

iii) Self-Sustaining Systems

Along with the expansion in irrigated area in most countries, has come a rising recurrent cost burden on national or state treasuries. This is so because in the vast majority of cases, recurrent costs are not funded from irrigation revenues, which are inadequate in any case, but from the general revenues of the state. Moreover, water is paid for by its users on an administratively-determined basis that usually bears no direct relationship to the quantity of water used. And even where there is some relationship between rate structures and quantities of water delivered, the farmer usually has little or no control over the volume or timing of those deliveries, rendering any incentive effect on him moot. In such a situation, cost recovery is low and financial incentives do not operate on either the irrigation agency or on farmers to encourage careful or judicious use of water. Raising water charges has virtually no effect on operational efficiency in this type of situation.

To break out of this cycle, it is necessary to reassess the basis on which irrigation agencies operate, raise their revenues, assess their institutional performance, reward and promote their staff, and share responsibility with farmers. Interesting recent

evidence from the Philippines and innovative but aborted experimentation in Sri Lanka, as well as several recent cross-sectional studies on irrigation system cost recovery, have suggested that there are ways to place public irrigation systems on a more self-sustaining footing, decreasing costs of operation, increasing revenues from direct beneficiaries, and providing incentives for more effective management on the part of irrigation bureaucracies. This is a most important area for further research.

In many ways such organizational restructuring is crucial to sustained success in many of the problem areas afflicting public irrigation systems. Unless systems of accountability can be established linking the two major participant groups in the irrigation enterprise--public irrigation departments and farmers--then there is little reason to expect system-oriented problem-solving behavior on the part of either. Furthermore, continued growth in government outlays for Operations and Maintenance (O&M), and in the gap between revenues and expenses, will create strong pressure for reductions in operating expense funding (as opposed to personnel budgets which are far more resistant to reduction) and for deferred maintenance. In such a situation, the required improvements in operating efficiencies will be difficult if not impossible to achieve.

In a larger sense, irrigation agencies must develop the capacity to manage the adaptive change process itself. One sure companion to economic development is the increasing pace of

change. Irrigation systems designed 50 or even 15 years ago are today typically called upon to perform different functions and satisfy different objectives than those they were designed for. To adapt to changing needs requires a capacity to assess changed conditions and needs and develop appropriate response strategies--a process which most irrigation agencies are ill-equipped to instigate and manage.

From a longer-range perspective, the fundamental "solution" to the problem of sustainability is the development of a set of institutions which work together to provide the capacity to deal with change. Irrigation agencies must play a leading role in this, but cannot be expected to carry out all of the specialized study, training, and advisory functions involved themselves. Thus sustainability is, at its roots, an **institutional** problem that extends to include the irrigation agency, farmers, and supporting organizations.

iv) Irrigation and the Resource Base

In the best of circumstances, irrigation development captures and puts to productive use a renewable resource of enormous potential benefit which would otherwise have little economic utility. Indeed, the food security of many nations depends critically on the productivity of their irrigated lands. At its worst, critics argue, it buries fertile valley bottoms beneath millions of cubic meters of water, displaces thousands of people, and leaves saline deserts in its wake.

Of all of the undesired consequences of large-scale irrigation development, salinity and waterlogging are probably the ones most frequently mentioned in the context of irrigation system sustainability. Estimates of their extent around the world vary, but they constitute a major and undeniable serious threat to the productive capacity and long-run sustainability of a large number of irrigation systems. (See report by Tereira et al. for IDRC).

Technical constraints here are often not the most serious ones. Economic, political, and institutional factors usually predominate where waterlogging and salinization (W&S) become threats. Major difficulties relate to the delayed onset of effects, the collective nature of many of the solutions, the restricted political constituencies supporting remedial programs, and the high costs both of constructing drainage systems and operating and maintaining them.

In some situations, there is no alternative to the installation of extensive surface or tile drainage systems in previously irrigated areas. Major drainage programs, for example, are underway in Egypt and Pakistan's Sind Province. In other cases though, and as a complement to the installation of drainage systems, are a number of non-structural measures which can have a significant impact on alleviating problems of waterlogging and salinization.

To the extent that W&S problems stem from over-irrigation, a major causative factor, the measures outlined above that reduce the incentive to use more water than necessary also alleviate W&S problems. Additionally, systems which transfer at least a share of the costs of treating the problems to those whose actions influence their creation can also be effective.

One of the most interesting approaches to this difficult problem lies in the creation of farm-level incentives for water table control. An example is the case of the Punjab in Pakistan where 200,000 private tubewells installed in the past 15 years to supplement canal water deliveries have had an important impact on controlling rising regional water tables. The search for ways to stimulate private investment in water table control and other non-structural ways of dealing with resultant W&S problems deserves much more attention that it is currently receiving.

PART 6

Human Influences on Sustainability and their Management:

1. The growing impact of human activities on the global environment.

Natural ecosystems, undisturbed by anthropogenic influences, have a high degree of sustainability. The climax vegetation may change over time for better or for worse, mainly as a result of climatic change, but such changes are generally gradual. Human intervention, particularly through cultivation, can lead to rapid destabilisation; major changes in species composition, a reduction in botanical diversity; and, because some cultivated plants and livestock are introduced from other regions, new pests, diseases, and weeds.

Thus agricultural systems are often less resilient than the natural ecosystems they replace, which are the result of long-term evolutionary processes; and many of the agricultural practises which have been developed over time are designed to protect crops and livestock against stochastic shocks, to which a stable natural bioclimax would not be particularly vulnerable. If those measures fail, the agricultural system may no longer be sustainable and either new safeguards have to be devised, the system has to be changed, or the area has to be abandoned. A simple example is the export of soil fertility through continuous cropping and sales of produce from farmland without restorative measures such as fallowing, green manuring, application of organic manure, or fertilizer. Productivity may be increased, maintained more or less on an even keel, or run down according to

the adequacy of the measures adopted to maintain the nutrient balance. Thus prudent management is the key to sustainability.

Over time anthropogenic factors interacting with climate, have become the principal agent of change in the natural environment. Their influence is both direct and situation-specific through agricultural activities, mining, and urban development; and indirect through actions in one area affecting the environment somewhere else: for example, upstream activities in a river basin causing changes in areas downstream, or atmospheric pollution originating in one region damaging human health, crops, or livestock downwind (acid rain, nuclear accidents). Such problems can be mitigated or exacerbated by good or bad management; and while historical experience, inherited knowledge, and learning from others can help to improve management; new situations create a need for new knowledge which has to be acquired through trial and observation.

The rate and complexity of change in the global environment in the present century as a result of the growth of human population, the expansion of agriculture to new regions, the development of new agricultural technology, industrialisation, dependence on fossil fuels for energy, and the spread of vast urban connurbations, has exceeded anything in previous history. Such changes are unlikely to be less rapid during the next fifty years, and unless they can be monitored, understood, and managed they may destabilise the environment and make sustainability increasingly difficult.

Agriculture is the most diverse and widespread human activity, and is practiced across a huge range of ecological and

social situations, by about 50 percent of the world's population, and nearly 75 percent of that in the developing countries; often in conditions where several variables are out of the direct control of its practitioners.

Because farming is essentially a process of interaction between human influences, climate, land and water resources, and technical change, producers responses to new demands made upon them by market forces or imposed by stochastic shocks are generally slower and less uniform, as well as more difficult to monitor and evaluate, than those of industrial firms. Many of the effects, especially those affecting the stability and sustainability of the resource base, are time lagged; sometimes over long periods, especially where trees or livestock are involved.

Moreover in developing countries, because of the very large number of producers and the small size of many holdings; it is often difficult to develop and disseminate new knowledge and technology, appropriate to the wide range of specific biological and socio-economic situations which may need to be covered. Yet loss of sustainability due to failure to respond to change in one region or even one holding may boomerang on others.

Finally, managers of small farming units - whether owners or tenants, are usually short of capital; unless little additional expenditure is required to enable them to benefit from new knowledge, their ability or willingness to respond is limited.

While it is often difficult for individual producers to respond to changing situations adequately and unaided, solutions to many of the problems and constraints they face which are

outside of their control, are within the capacity of their governments to solve, and the severity of others could be reduced by international action. Thus sustainability depends critically not only on the ability of millions of producers to manage their resources efficiently, but on measures devised and resources made available to them by their governments to help them do so, sometimes with outside assistance.

The stability of the policies from which these measures are derived, and the support provided to the institutions through which the policies have to be implemented, and knowledge and resources channeled to producers, is therefore crucial to the success of their efforts to achieve sustainable production.

2. Major institutional issues affecting sustainability

i. Political Instability:

We assume here that the 'body politic' of a nation is an institutional mechanism whose task is to guide, develop, and facilitate the implementation of policies designed to promote national welfare. We further assume that sustainability of the means to production will be an integral part of such policies, although the path by which this policy objective is achieved may vary widely among countries according to resource endowments and technology. Errors of judgment by policy-makers in the allocation of resources, or in the priorities given to various social groups in attaining these goals of sustainability may lead to failure, unrest, and even to the fall of the government.

Instability in policies directed to sustainability may thus be caused by political incompetence; however, political

instability has itself been an important cause of lack of sustainability, even when the policies were sound.

Oram has noted that out of 16 African countries which failed to achieve an annual agricultural growth rate of 1 percent or higher during the period 1965 and 1980, no less than 13 had had one or more major political crises during that period (civil war, invasion, or a major coup). In most cases the instability thus created compounded difficulties arising from the transition from colonial dependency to independence - which itself sometimes had to be fought for. No region in the world except the South Pacific, has a higher population of 'young' countries than Africa.

In a recent paper Idachaba (1987) has dramatically illustrated the problem of instability created by frequent political change by reference to Nigeria, which has had 6 Heads of State and 9 political and 7 administrative heads of the Federal Ministry of Agriculture between 1969 and 1986; as well as a bruising civil war. Not only has this caused discontinuities and inconsistencies in policy and its implementation (as illustrated by an earlier Idachaba study of the Nigerian agricultural research system), but each new administration has in some ways to dissociate itself from the policies of its predecessor, and to go through a time-consuming learning process before it can formulate and implement successful new policies. Such difficulties tend to be compounded in one-party states or dictatorships where there is no shadow government; and where a successful coup may overturn the entire structure and composition of government including most of the civil servants.

It is difficult to maintain sustainability and continuity of policy - even sound policy, in any given sector of the economy in the face of such upheavals, especially if there is also a breakdown of law and order. Idachaba argues that within a given regime policies should be sound and well-implemented so that poor agricultural performance does not itself become a source of instability, and that to the greatest extent possible the main elements of the policy package should be regime and sectionally neutral, widely disseminated, and understood to be beneficial by a wide spectrum of producers. If this can be done there is some hope that any new government will maintain continuity.

It is worth noting in this context that while governmental instability and vacillating policies are certainly inimical to the attainment of sustainability; stability as an end in itself may not be sufficient to achieve this goal.

Political regimes may be stable but yet inflexible or repressive; placing a premium on conformity and servility rather than on innovation and initiative. Even if this is not the case, more than a continuation of the status quo is likely to be required in most countries if new challenges are to be overcome. As we have suggested earlier, bold measures and innovative attitudes to sustainability are likely to be essential.

Usually when political upheavals occur external agencies or the CGIAR can do little initially but maintain a watching brief. However, unless the new regime is demonstrably repressive, or unstable, outside assistance and willingness to cooperate where needed should not long be withheld because of political slogans

or semantics. Recent history has shown that initial hard-line attitudes may not long persist in the face of pressing problems.

ii. Gaps in mechanisms for policy formulation

In many developing countries serious deficiencies exist in the mechanisms, procedures, and staff capabilities for the formulation of agricultural policy.

These deficiencies are of four main types:

- Gaps between top-level planning authorities at the national level (usually located in Ministries of Planning, Finance, Economic Development, or the Prime Minister's Office), and line Ministries such as Agriculture or Natural Resources. This leads to the setting of unrealistic targets in national plans, as well as to in adequate resource allocations for their achievement.
- Communication gaps between senior planning officials in Ministries responsible for Agricultural development, and heads of services responsible for plan implementation (Research, Extension, Marketing, etc.)
- Poor linkages between heads of services under agricultural ministries, reflected in lack of coordination in program implementation.
- Absence of arrangements to allow participation of producers, producers' organizations, and other private sector entities in the implementation and evaluation of agricultural projects and programmes.

The first of these weaknesses stems partly from elitist attitudes of national planning agencies with respect to line ministries; partly from the absence of staff in the latter who

have the training and experience to deal with senior planners on equal terms. The same applies to a significant extent to the second gap: Ministries of Agriculture may be weakly staffed in social sciences; research and extension services, especially in smaller countries, sometimes have none at all.

This situation is frequently aggravated by fragmentation of responsibilities for agricultural development among several Ministries, including Science and Technology Agriculture (crops), Livestock, Natural Resources, Forestry, Irrigation, Education, and Rural Development. Even commodity responsibilities may be divided among several Ministries. These various agencies may be dealt with piecemeal by Planning Ministries, in terms of policy directives and resource allocations; while they may compete with each other for resources in dealing with those Ministries and with international research centers or donor agencies. They may have their own research and extension services, and deal with producers only with respect to their own interests, and not holistically in concert with staff from other services in a systems approach to agricultural development and the introduction of improved technology.

Various devices have been introduced to try and strengthen these inter-Ministerial and inter-service linkages, with varying degrees of success. They include Science and Technology Councils, or Agricultural Research Councils, with wide Ministerial representation, usually under the Chairmanship of the Agriculture Minister, but sometimes under the Ministers responsible for Planning, Science and Technology, or even the Chief Minister. Where such Councils have limited financial

jurisdiction they have not been very effective; and in smaller countries their size and the fact that a trained secretariat is needed to service them properly may be a burden.

A recent (1986) ISNAR review of the organizational structure of national agricultural research systems in 81 developing countries shows that in almost half (38), research is still carried out predominantly under control of line Ministries. In 18 it is undertaken largely by an autonomous agency with a broad mandate; in 11 by several different entities without a central coordinating body; and in the remainder under the aegis of a coordinating council. The autonomous agency pattern predominates in most larger Latin American systems; central coordinating bodies exist in several other larger developing country systems (Bangladesh, Brazil, India, Nigeria, Pakistan, the Philippines, and the People's Republic of China), but they are also found in several small systems.

ISNAR concludes that in Asia and Latin America effective institutional changes have taken place in response to a clear economic need, an expectation that technology would provide a solution, and a perception by decision-makers that structural change was necessary to meet that need. It is nevertheless difficult to identify any generalizable conceptual model of an ideal research system: the optimal format varies according to political, structural, and technical factors within a given environment. The degree to which decentralisation increases the effectiveness of a national system depends both on ecological and social diversity, and on the national, political and administrative structure.

The role and stage of development of the private sector is also important. Effective private sector research can be highly complementary to that undertaken under government auspices, but there is some danger that if the public sector institutions are left to tackle the more difficult and unresponsive problems and areas while commercial research picks up the plums, returns to public expenditure may appear to be low, and budgetary support to the latter will be reduced.

In addition to ISNAR's work, evaluation of national research and technology transfer systems has been undertaken by a number of other institutions and development assistance organizations, including FAO, UNDP, The World Bank, USAID, GTZ, ODA, IADS, the East-West Center, the Overseas Development Institute and IFPRI. In some cases these studies have involved a review of the work of the organization concerned in support of national research and extension programmes.

Their conclusions on the optimum system approaches to the performance of research and extension functions vary (FAO, for example, favours making research the responsibility of one, preferably autonomous specialized organization under the aegis of the Ministry of Agriculture, whereas some others seem to lean towards research councils). The World Bank has been actively propagating the Training and Visit (T&V). system of extension for developing countries; whereas some extension specialists regard it as too programmed and inflexible to meet any but the simplest needs. Obviously, more research is needed on the appropriate institutional mechanisms for successful research and extension operations. ISNAR suggests that this should include more

in-depth analysis of how selected systems evolved and adapted themselves to national environments, and how they have changed over time since their inception in response to changing political conditions and the country's progress and stage of development.

Nevertheless, despite their different viewpoints on some aspects of organization, these studies are virtually unanimous on certain issues of sustainability. These are:

i. Political will and commitment from government is vital. This applies especially to research, where long-term stability is essential, and the most successful institutions have evolved over periods of 20-25 years.

ii. Agricultural research is still widely under-funded, despite evidence of high financial returns to research investment. However, according to the FAO/UNDP Study (and this is not always so widely recognized in published reports), unless research investment is in balance with that on extension, seed production, and other services, those services will suffer and research results may not get out to farmers. The allocation to research of between 10-20 percent of the total funds committed to agricultural development, or 1 percent of agricultural GDP is advocated by that study. Varying normative targets for research expenditure by developing countries have been suggested by different authorities; ranging from 0.5 to 2.0 percent of agricultural GDP. The first figure is probably too low (although several Asian countries with large, relatively efficient systems, have not yet reached it, because their salaries and other costs are very low). The higher figure (hardly attained by any country - developed or developing) may be too ambitious. iii.More

critical analysis is still needed with respect to the optimum allocation of financial resources within and between the various services which together provide public sector support to agriculture, as well as their complementarity with the private sector. In particular the balance between capital, salaries, and recurrent funds for research operations is a matter for concern since operational funds are declining in many countries in proportion to salary costs; partly due to inflation, partly to increasing numbers of trained staff entering national systems as training arrangements expand. It is much easier to make cuts in operating funds than in staff salaries; even though the result may be that more, and often better trained personnel, can do less and less effective work. A third cause of this phenomenon is proliferation of donor support for research, both through institution - building and projects involving research components. Thus national governments may take on commitments which they are unable to sustain from their own budgets once donor support is phased out. While lack of financial continuity is the commonest problem, scientific continuity may also suffer if a programme depends too heavily on expatriate support.

iv. There is mounting evidence that wide fluctuations in public funding of agricultural services are extremely harmful to effective operations. Their impact is both direct on the conduct and timeliness of work; and indirect, through depression of staff morale.

v. Horizontal linkages between government services are often weak. This seems to be particularly serious between research and extension, but it applies also to information,

marketing, and input supply services. Various attempts have been made to find solutions through inter-service councils Ministerial chairmanship; research-based subject-matter specialists in T&V systems; extension-liaison units in research services; and farming systems type research; yet the issue comes up repeatedly. Part of the problem seems to stem from isolationist attitudes by researchers; part from the fact that any linkages which may develop between senior officials at inter-service planning levels are often of a personal nature and are not repeated lower down in operational activities, either because of hierarchical rigidities or weaknesses in diffusion of information and directives from the centre out to the field staff.

These criticisms are so frequent and widespread that closer monitoring and evaluation of the mechanisms which have been introduced to solve them in various national situations seems urgently needed. At one time research was widely neglected; since the early 1970's 'research on research' has received increasing attention, as well as larger resources being channeled to research operations. It now seems that research on extension and related services needs reinforcing: no CGIAR institute is charged specifically with such a responsibility despite the importance of the issue to the adoption of research results. It is also noteworthy that missions asked to advise Third World governments on research, rarely deal in any depth with its backward and forward linkages to other services. Perhaps they are not given enough time to do so; but it seems that an important opportunity to learn more about problems of communicating with producers is thus being neglected. The

linkage between research and extension should provide for a two-way traffic of new knowledge and technology to producers and a feedback of information from the field, both with respect to producers' needs and problems and concerning the effectiveness of the research output in finding solutions to those problems. In many countries this process seems to be ineffective, but the reasons for this are often unclear.

In recent years farming systems and on-farm research have been widely seen by development planners as providing solutions to this long-standing failure to bridge the gap between the generation and diffusion of improved agricultural technology. While some progress has been made through this approach, concepts of farming systems research vary almost as widely as those about sustainability. Some national research systems show a good deal less enthusiasm for FSR than developed country donors; possibly because a well-equipped FSR programme is demanding on skills, staff from several disciplines, and recurrent funds, and trying to run one on a shoestring is worse that none at all.

An issue which may need further thought with respect to the future evolution of technology for the Third World, is whether and under what conditions conventional concepts of research, extension, and their interaction are still appropriate. A number of questions may be raised on this issue-for example:

i. Are too many fixed assets being sunk in weakly-staffed research stations scattered around the countryside andsometimes poorly staffed and located to deal with changing cropping patterns and socio-economic situations? Would not some concentration of resources be more cost-effective, enabling

higher quality scientific work to be done at better equipped stations. Under what circumstances are single commodity or factor-oriented stations preferable to multi-purpose ones?

ii. How best could farming systems and other location-specific problems be dealt with? Has sufficient advantage been taken of improved mobility to achieve multiplier effects in adaptive OFR and FSR while avoiding permanent stationing of large numbers of researchers in isolated areas. What is the optimum balance between station-based and field research staff?

iii. How can opportunities be given to field research staff to publish and not to be treated as somehow inferior to 'laboratory' scientists.

iv. Should research and technology transfer (extension and information functions) be merged? If not, how can they be more effectively associated; and what, if any, role should extension staff have in FSR, OFR, or other research?

v. Under what circumstances are contacts between extension workers and individual farmers still essential, as opposed to group methods, and use of mass media? Are extension staff either adequately equipped or trained to enable them to make effective use of modern communication and teaching aids?

vi. Should extension staff have any responsibility for the provision of inputs to farmers? If not what is the best way of increasing farmer's access to them?

vi. The involvement of producers in the planning and implementation of government-agricultural development-policies is generally small, and frequently non-existent.

Many studies of the factors conducive to sustainability argue that failures to achieve lasting benefits from rural development efforts are frequently caused by top-down planning and lack of involvement of the potential beneficiaries in the formulation of the plans or in their management. The need for local people to be brought into this process very early on has been stressed by Arnold with respect to forestry, Gous concerning grazing management in Africa, Dudal in relation to soil conservation, Wolman on conflicts of land use over game reserves, and Schubert in reviewing the results of twenty-four national development projects evaluated by GTZ in several different sectors. This review observes that in only one of the six projects where all groups involved in or affected by the project took part in the planning, did any subsequent conflicts over objectives arise; whereas in nine projects where the target groups and others important for the project were not included in the process of defining objectives, a chain of negative effects could be observed as the projects evolved.

In a review of approaches to achieving participatory actions Sachs, citing an experience from Nepal, states 'Wherever we take up the priorities as formulated by the villagers themselves, enthusiasm comes up as a result: People cooperate, they pull us, not vice versa'.

At the same time involving people initially is not easy. Historically they are often not used to involvement and consultation, therefore, their attitude may be passive or even suspicious. Issues may be raised which are contentious within the community, which appear to benefit some groups more than others, which run contrary to established customs (involvement of women or landless), or which would benefit one community largely at the expense of others (tapping a water source which cuts off supplies to another village). Questions of individual or sectional interest versus society can cause feelings to run high. Thus a careful process of social science action research may be needed before the factors hampering participation can be identified, priorities established and firm plans formulated and implemented. This may be unpopular with governments because it delays action or because of pressure from local influence groups.

Sachs notes that published empirical studies of successful participatory action schemes are rare; although a forthcoming conference on sustainable development under the aegis of the International Institute for Environment and Development identifies about thirty case studies, many of which are based on cooperation among government services, donors, and local people. The experience gained in these studies should be drawn on widely by planners and researchers.

The issues seem to be i) not whether, but <u>how</u> local knowledge and experience can be tapped to complement the expertise of formal planning agencies as an aid to problem identification and the formulation of more realistic plans.

ii) How, and in what operational format, people participation in the actual implementation of the development strategy for their region, can be achieved. This may require modification of the formal institutional and administrative structures.

iii) What supporting services and funds are required to make local participatory action self-sustaining. This may imply financial support to enable people who have limited resources and poor credit ratings to initiate activities which raise their cash incomes and provide additional employment. Formal banking institutions, government credit agencies, even rural cooperative organizations are often unwilling or constitutionally unable to provide such funds. Sometimes they have no facilities in the area concerned. Imaginative and flexible procedures, and strong government support may be necessary to overcome such obstacles.

Nevertheless the opportunities appear to be great, and imply a major challenge to conventional concepts of development. Studies of innovative approaches adopted in South Asian countries point to how local group endeavors can be helped to become financially sustainable.

This is an area in which the CGIAR has so far been little involved possibly due to failure to recognize the need, or because of its time-consuming and often location-specific nature. Whether it should now be given higher priority in Social Science research by international institutes, presumably in collaboration with other international or national research organizations is a matter the TAC may wish to consider. Perhaps it might be incorporated into Centie's work on agro-ecological

characterisation, recommendation domains, farming systems, agro-forestry, or inter-sectoral linkages.

vii. Sustainability and education.

A presumption might be that the effective involvement of local people in development planning and implementation would be greater if their levels of literacy and education were higher. There is not much direct evidence of this, possibly because of limited evaluation of projects involving genuine people participation; and the fact that traditional hierarchical village leadership is often based on inherited influence rather than education (although the former may predispose to the latter). Also the resource - poor, landless, and women tend to be discriminated against in education, even though they may need it most to escape from poverty or servitude.

There is, nevertheless, evidence from World Bank Studies, that primary education yields significant returns to investment, farmers having several years of basic schooling being more effective users of technology than those without education. It is not a substitute for experience, but it enables them to profit from new knowledge and to be more discriminating in their decisions as to how best to blend traditional and new techniques of production.

Economic evaluation of returns to education also indicates that larger benefits accrue to investment in primary than to higher education, especially that of University-level. This has sometimes been used as an argument against donor support of investment in higher education and training in developing countries, on the grounds that it does not benefit the poor.

On the other hand, the constraints imposed on the development of technology appropriate to local needs by inadequate numbers of well-trained scientists in national research systems is a recurring theme of most studies of national agricultural research systems in the Third World. This is likely to be exacerbated if more emphasis is to be placed on decentralized research on farming systems, agro-forestry, agro-ecological characterization and understanding of rural social problems, whether by international centers, through networks, or by individual national institutions. It is noteworthy that several of the stronger and more successful national systems have developed in countries which have given long-standing support to higher education.

Thus we do not feel that this is an either - or issue. However there are some important questions requiring evaluation. These include:

- How can greater equity be achieved in primary education, so that socially or economically disadvantaged groups have equal opportunities. Although considerable progress has been made in enrolling female children in primary schools, fewer go on to secondary schools than is the case with boys, and the drop-out rate is much higher.
- What proportion of the educational curriculum in rural areas should be devoted to vocational aspects of rural life, and what to general education?
- How can older people in rural areas be given access to basic learning skills, and better equipped to understandand be able to deal more effectively with the various

sources of information on technology, credit, inputs, home economics, and other skills which may be available, but not well-known or readily accessible to them?

- Are rural people and areas discriminated against in secondary education, so that access to universities is mainly confined to urbanites. This may contribute to a class of agricultural scientists divorced from rural realities, compounded in some cases by overseas training in an unrelated environment.
- How can universities contribute more effectively to the formulation and achievement of national agricultural research priorities? What proportion of their staff time should be devoted to research? Is there an appropriate division of labour between universities and NARS.

Most studies of NARS are surprisingly weak on all aspects of education, both in relation to research itself, and to the adoption of research results. University research is rarely dealt with in depth, its contribution evaluated, or its limitations probed. Thus empirical evidence as to its importance, and how it can be linked most effectively to complement other research is limited. The fact that University research is usually under a separate ministry to agriculture is not a sufficient reason to treat it lightly. This aspect of education seems to merit greater attention by the TAC, the CGIAR, and by research review missions.

Infrastructure and sustainability

The role of infrastructure in sustainability has been somewhat of a bone of contention. As mentioned in our discussion of resource management, roads have not proved an unmixed blessing in forested areas, even though necessary for timber extraction, as well as for management purposes. Their contribution to overgrazing is also an issue; although Glantz has shown that some of the worst livestock losses of the first Sahelian disaster might have been avoided if herders had had better access to markets; road building has also contributed to environmental pressures as a result of the spread of cultivation into existing grazings and movement of grazing animals into more remote areas. Roads have sometimes proved excessively costly in relation to the size of their economic and social benefits, or have had damaging repercussions on indigenous local people. Thus some donors have been reluctant to give high priority to infrastructural investments.

Nevertheless, the evidence is strongly supportive of infrastructure as an agent of sustainable development in most circumstances; especially with respect to raising yields and cropping intensities. It facilitates regional and on-farm research to help develop more acceptable new technology; the provision of services to producers and access to input supplies and markets for produce. Better transportation can open up new on and off farm employment opportunities based on technological change and inter-sectoral linkages, as well as providing improved access to food security programmes, banking, education, health, electricity and other facilities which raise the quality of life.

Studies by IFPRI have shown that the absence of services is one of the major causes of poor production performance in the smallholder sector in Africa, where transportation systems, including both road and rail networks, are usually poorer than in Asia and rural population densities are generally lower. Raisuddin Ahmed has shown that in areas of Bangladesh with good infrastructure there are significant increases in the levels of adoption of new technology, in the proportion of land devoted to high-valued crops, in employment, and in prices of marketed produce, as well as wage-rates, compared to areas with poorly developed infrastructure. Wages increased by 54 percent, and low productive activities were replaced by more highly productive jobs in the better areas, with increased off-farm and non-crop employment. Ahmed demonstrates strikingly lower marketing costs, and thus greater competitive power on international markets in Asian countries compared to Africa. Asian farmers received on average 75-85 percent of the price paid by final users, whereas African farmers only received 30-50 percent. Half of this difference is attributed to better infrastructure in Asia. Comparing Zambia and India, Wanmali found that the services were much better distributed and more widely used by each household in India; the area served per service being 24 sq. km. there and 824 sq. km. in Zambia. Moreover, 60 percent of users in Zambia travelled on foot to service centers, compared to only 25 percent in India, where 45 percent of these using services did so with mechanical transport, compared to only 11 percent in Zambia. The most widely used services by small and large farmers in India

were those connected with inputs and animal health. Wanmali concludes:

- Greater distances imply less use of services, and higher rural incomes can positively influence service use.
- In India, higher rural incomes were the result of a government policy of simultaneous provision of irrigation, electrification, roads, and rural service centers to facilitate the use of modern agricultural technology within the rural farming population.
- The location of the services in India was planned based on analysis of the demographic, functional, and spatial characteristics of the region's settlement system. The private sector was influenced in its decisions to provide complementary rural services by the initial government investment in such services.
- Approaches to the solution of problems of agricultural development in Sub-Saharan African in general and Zambia in particular will require interdisciplinary research and simultaneous action on agricultural research, technology diffusion, input distribution, and the development of ruralinfrastructural services.
- More research needs to be done on these aspects before Sub-Saharan African countries can expect to identify the optionsavailable for appropriate planning of agricultural development.

A study by Von Braun on poverty allocation in the subsistence farm sector of Africa provides confirmatory evidence. He shows that absolute poverty in the African farm sectors is charac-

terized by:

- low real income combined with low cash income. This cash income frequently depends upon primary source;
- insufficient food consumption combined with high seasonal fluctuations in consumptions;
- inappropriate access to services, such as health services (or the ability to acquire them), resulting in high morbidity, infant and child mortality, and low life expectancy. High adult morbidity adversely affects labor productivity in agriculture.

Von Braun states that the importance for the poor in rural Africa of off-farm nonagricultural income sources is frequently underestimated. The rural poor in Sub-Saharan Africa typically obtain 30-40 percent of their income from nonagricultural sources. Better infrastructure increases opportunities for diversification of production and employment.

This work shows that poor rural households spend most of their cash income on food; thus there is little left over for other essential expenditures. Therefore, to reduce the cost of getting access to services such as health facilities, clean water, and food supplies in times of crisis, these services must be moved closer to the rural poor. Improved infrastructure is crucial for poverty alleviation in rural Africa. It might also be asked, (although this question is rarely addressed in these studies), whether remoteness or poor access, does not bias development assistance and government personnel to concentrate resources in ares which are better served by transportation. Certainly a good deal of the breakdown of food security, and the

difficulties faced by relief agencies in attempting to get emergency supplies to affected areas can be traced to lack of infrastructure and weak government services, health and other facilities in those areas.

We feel that the evidence is strong that infrastructure generally plays an important and probably under-estimated role in sustainability. More research is needed on some important issues including:

- The approximate main and feeder-road densities and widths to serve specific rural populations, and the economies of scale of serving widely dispersed high potential areas with intervening areas of low potential. The potential savings from wider use of four-wheel drive vehicles and animal transport in lieu of all-weather surfaces.
- The optimum ratio of all-weather to other roads;
- The complementary between road,-rail,-water, and air transport networks.
- The optimum location and dispersion of research facilities in relation to infrastructure.
- How to prevent increased environmental deterioration as a result of road construction providing easier access to particularly fragile agro-ecological zones.
- Meeting recurrent costs of maintaining vehicles, infra-structure, and other linked services (electricity, health, water, agricultural extension, veterinary). This has proved the nemesis of many transportation and other projects to improve rural infrastructure.

PART 7

Macroeconomic policies and their influence.

The Impact of the macro-economic environment on sustainability

Many studies emphasize the interdependence between investment in research, the demand for and adoption of new agricultural technologies, and the national political and economic environment. The latter, in turn, is subject to external economic pressures over which an individual government may have only limited control; including, in particular, policies of developed countries with respect to trade and foreign aid. Instability in either domestic or foreign economic policies can adversely affect sustainability of the agricultural sector: wise policies and the avoidance of sudden changes in important economic parameters can provide incentives to sustainable growth.

At the national level, both the external economic environment and internal differences need to be taken into account in developing a coherent land-use and technology policy. Binswanger (1986) has pointed out that because prices of factors of production differ sharply across regions, a technology which achieves identical technical input savings in all locations will not necessarily be equally profitable everywhere. Thus, innovations are sensitive to the economic environment, just as much as the agroclimatic and soils environment. Moreover, as Mellor (1985) has emphasized, the impact of new technology on relative incomes varies within a country both between different geographic regions and among different peoples within the same region. Ways have to be found of coping with the significant

political and economic consequences of these differentials without inhibiting the production-increasing potential of new technologies. This is important because discontinuities in the growth performance of agriculture, especially in low-income, developing countries have a chain reaction throughout the economy; affecting household nutrition and food security, widening inequities between ecological regions and social groups, reducing foreign exchange earnings, and exacerbating political instability at the national level. And Idachaba has noted that in political regimes with a high degree of mass-illiteracy and social disarticulation there are no effective mechanisms via the budgetary processes for the gainers from such discontinuities to compensate the losers. The latter simply lack leverage and political clout to make their demands known.

Evolution of government policies towards agriculture in developing countries.

Government policies towards agriculture in developing countries have differed within and between geographical regions both as a result of their historical evolution and of their resource endowments. The emphasis given to investment in agriculture versus other sectors, the type of agricultural investment, the emphasis placed on technology as opposed to horizontal expansion into new lands, the extent and nature of State intervention in the economy, and the institutions created to develop or to exploit the agricultural potential have varied greatly. Time has also played an important part in determining

the type of government intervention and the role accorded to agriculture by national policy-makers.

As a broad generalization, major geographical regions achieved independence from colonial rule in the time sequence: mainland Latin America, Asia/North Africa, Sub-Saharan Africa, Caribbean, South Pacific; although some countries never suffered colonial status. The development of their infrastructure, and the maturity and stability of their institutions has followed a somewhat similar pattern. Latin American countries have probably adopted the most laissez-faire attitude towards agriculture and the development of the private sector; Asia, especially South Asia, has tended to rely more heavily on public institutions, sometimes appearing to discriminate against agriculture in favor of industrial investment and against privatisation of agriculture (for example in fertilizer distribution and seed production); and in Sub-Saharan Africa governments have experimented with many institutional forms, mostly designed to facilitate active state intervention and control of land, the means to production, and the marketing of produce.

Nationalization of private estates, establishment of state-run mechanization schemes, creation of State marketing boards, and control of free-market sales are well-known examples. These have generally created disincentives to private producers, either through price controls designed to favor urban consumers, or because of taxes levied on marketed products; while they diverted a high proportion of capital investment and trained human resources from support to increasing production in the private sector, without a compensating expansion of production

from public enterprises or a reduction of costs of production or marketing. Their creation reflected a perception that massive State involvement in all aspects of agriculture was the best, if not the only way, to achieve rapid growth in a short time, but the effect was often the opposite. Domestic production stagnated; export markets were lost - mainly to more dynamic Asian Competitors (see Idachaba on Nigeria and Tanzania, Nweke on Ghana, Delgado on the Ivory Coast); and neither consumers nor producers benefited in many African countries. The causes were numerous, including:

- ideological approaches imposed from the top on agricultural development and nationalization of private enterprise.
- lack of trained managers and operatives (especially in mechanization schemes) to run State enterprises.
- poor allocative efficiency by governments, both between other sectors and agriculture (Ghana being a classic example), and within agriculture - especially with respect to foreign exchange for input purchase and delivery.
- use of state mechanisms to impose penal levels of taxation on agricultural producers or exporters. This 'killed the goose' in several West African countries.
- failure to appreciate and maximize local ecological and social differences and comparative advantages in development plans and in the creation of institutions and infrastructure.

A majority of African countries have now come to realize that massive State control is not going to solve their economic problems, nor achieve self-sustaining agricultural

growth. Many of the institutions established to foster State intervention have been dismantled or substantially modified. However, agricultural growth in Sub-Saharan Africa still lags well behind that in other developing regions, and many countries are still experimenting with institutional innovations designed to accelerate agricultural growth among the small producers. The success of these experiments, including those in agricultural research and technology transfer systems will crucially determine future progress in African agriculture. It deserves every support from donors and international research institutions. Perhaps the CGIAR institutes (including IFPRI) have remained too detached from research related to institutional innovation in agriculture, with the possible exception of its direct impact on adoption. The issues involved are much wider than this, however, and appear to require closer attention.

Prices and exchange rates: effects on sustainability

Macro-economic policy has a powerful influence on sustainability of agricultural production through the incentives or disincentives it presents to producers, its impact on consumption and demand, and its impact on political stability. Decisions as to prices and exchange rates favor some producers more than others, and producers and consumers differentially. Thus, attempts by governments to introduce new price policies which reduce the advantages enjoyed by sectional groups may lead to serious political unrest - even if the ultimate results of those reforms might have been beneficial to a wider social stratum.

In the agricultural sector the effects of price changes and exchange rates are closely interwoven with technological change, and with changes in land use. If demand is inelastic but supply is elastic in response to price, either because of the technological potential or because of the availability of new land, price increases may generate a considerable increase in production in a protected market, which then becomes a political embarrassment. This is the situation with the European Common Market. Conversely, where supply is inelastic, either because of lack of yield-improving technology, land and water constraints, or other inhibiting factors, prices may be ineffective as an instrument of change. This may be the case in a number of African countries.

In general, it is widely agreed that over-valued exchange rates, artificially low internal prices that favor urban consumers, and deterioration in the external as well as the internal terms of trade for agricultural products, create serious disincentives to agricultural producers, especially if their capacity to respond involves higher risk, higher capital outlays, higher recurrent cash costs, or lost opportunities for part-time, non-farm employment.

To find ways of reducing these disincentives without taking unpopular and possibly unacceptable political risks is a key issue facing many governments, and not only those in Third World countries. However, because a prosperous agriculture is so crucial to the long-term economic and social welfare of a majority of developing countries, providing both the main source of employment, the engine of growth for future industrial

expansion, and the bulk of the foreign exchange, sound macro-economic policies favoring agricultural growth are particularly crucial there. What reforms may be necessary to achieve this goal will vary with the present level of development of a country, the nature of the agricultural resource base, existing price and exchange rate policies, and the flexibility of the national institutions and individual producers to respond to changes in policy. Nevertheless, certain common features can be identified i.e.

i. Overvalued currencies can lead to serious price distortions which adversely affect both domestic agricultural prices and agricultural export earnings. In general, overvalued exchange rates favor urban consumers by facilitating cheaper imports, both of food and luxury consumer items. They also favor capital-intensive domestic industries over labor-intensive ones, thus reducing employment opportunities. Some gains to agriculture may be achieved through lower prices of imported inputs, but if domestic food prices are forced down substantially by cheap food policies (subsidized largely by developed country exporters), very large cost savings from yield-increasing technology may also be needed, or producer incomes will not improve much.

Agricultural exports suffer especially severely, since the producer price of export crops is typically closely related to the conversion rate between foreign and domestic currencies; hence, the greater the differential the lower the price. Moreover, to the extent that the foreign exchange thus earned

goes to finance cheap imports, the urban consumer is being favored yet again at the expense of the rural producer.

The direct answer to this dilemma is devaluation, principally to shift the internal terms of trade back towards the rural areas and to divert capital and foreign exchange now used primarily for consumption in cities into agricultural development. This should stimulate the expansion of production and the use of cost-reducing technology, thus reducing domestic food prices without the necessity of input subsidies, and stimulating foreign exchange earnings through the revitalization of agricultural exports. However, if the gains from devaluation are to be sustainable and inflation controlled, complementary measures to foster trade liberalization and rationalize the tariff structure will be needed.

ii. Large abrupt changes in macro-economic policy are to be avoided. These can be counter-productive by causing serious political unrest; at best they are difficult to absorb without destabilizing effects on the economy. The issue is how to achieve the objectives of policy without running avoidable risks. Measures which may be unpopular with large or politically powerful segments of society must either be phased in gradually, or else accompanied by safeguards to mitigate adverse effects on at least some of those who lose as a result. These may take the form of tax concessions, wage increases, subsidies to disadvantaged groups (low-income families, the unemployed, pregnant women, children, pensioners), food stamps, food-for-work programs (for example, in connection with infrastructural

development). It may be especially necessary to safeguard the basic needs of the urban poor.

However, it is also important that once a phased program of economic reforms is introduced, it is maintained steadily and that the direction of change is consistent even if the pace is moderate. Stop-go or see-saw policies create disincentives to innovation through increasing risk and uncertainty. It must also be recognized that a policy geared to gradual change does not achieve instant miracles. There are lags between policies and their impact on agricultural production. Meanwhile, population continues to expand, urban more rapidly than rural, and incomes may rise. Thus, in the interim before a supply response occurs, food deficits may increase. This is a situation where concessional food supplied by donors could be very helpful, although prices will have to be carefully adjusted so as to avoid defeating the policies aimed at providing incentives to domestic producers.

iii. Macro-economic policies must themselves be sustainable. This is particularly important in the case of subsidized input and credit schemes. Idachaba has cited striking examples of the difficulties in maintaining pesticide and fertilizer subsidy schemes in Nigeria. These foundered through being initially over-ambitious in their targeted coverage, through bureaucratic inexperience and ineptitude, differences between Federal and State governments in subsidy policies and in their administration, heavy transportation costs in the case of fertilizer, lack of incentives to private enterprise, and foreign exchange problems. Finally, the fiscal burden became non-

sustainable. Similar experiences have been reported in other countries which have attempted to subsidize inputs, and not only in Africa. Credit schemes have also suffered problems of sustainability. Even when initial repayment levels are good they seem to decline progressively, for reasons which are not well understood.

iv. Employment growth provides incentives to increase food production without depressing prices.

Accelerated growth of food production is an essential part of high employment growth strategy in developing countries. Employment growth raises demand for food, since a high proportion of wages is spent on food. If food supply does not rise in parallel with employment, food prices increase, governments may adopt anti-inflationary policies which slow the pace of employment, or they may import food to keep prices down, thus running into foreign exchange problems which may curtail imports and drive domestic food prices up again.

Analysis of time series data on poverty and agriculture over one or two decades shows the two most powerful forces determining poverty to be per capita growth in food production and change in food prices. The first is a major determinant of the amount of employment. The second determines the purchasing power of a given level of income. Thus, to reduce poverty, the ideal is to increase food production and to lower food prices. How can incentives to produce more coincide with lower prices? By reducing the cost of production through technological change. But, can increased food production from improved technology occur without depressing food prices? The answer is to stimulate

sufficient employment growth in the nonagricultural sector to increase demand for food by as much or more than the increase in supply.

Accelerated growth in agriculture through production-increasing technological change creates demand for goods and services that are efficiently produced with low capital-to-labor ratios. In Asia, small farmers spend 40 percent of increments to income on locally produced nonagricultural goods and services and about 20 percent on labor-intensive produced horticultural and livestock products. It is the link between agricultural growth and labor-intensive nonagricultural growth that needs to be encouraged and that offers so much potential for concurrently increasing the rate and efficiency of growth. Thus the critical interrelations between agriculture, employment, and poverty alleviation are clear, as well as the trade-offs between employment policy and price policy. Accelerated growth in agriculture through production-increasing technological change creates demand for goods and services that are efficiently produced with low capital-to-labor ratios. In Asia, small farmers spend 40 percent of increments to income on locally produced nonagricultural goods and services and about 20 percent on labor-intensive produced horticultural and livestock products. It is the link between agricultural growth and labor-intensive nonagricultural growth that needs to be encouraged and that offers so much potential for concurrently increasing the rate and efficiency of growth.

v. Trade liberalization by developed countries could contribute substantially to sustained.

Developing countries (LDCs) typically have open economies in which agriculture is of substantial, if not dominant, importance. For most LDCs, the conditions they face in world markets largely determine the options open to them in formulating their own development strategy. Conditions in the international commodity markets, and the financial and exchange rate markets, along with foreign assistance, delineate the external environment that will be major determinant of the economic prospects for LDCs for the next decade. For many LDCs, agricultural trade is an engine of growth. They depend heavily on agricultural exports for their balance of payments and for income. Moreover, international trade is an integral part of food security for many LDCs that use food imports to supplement domestic output. The degree of protection given developed-country agriculture is significantly greater than is given to manufacturing. In most LDCs however, agriculture is usually taxed and manufacturing is projected from import competition.

In world markets, trade in temperate region products and some tropical products, like sugar, is influenced most by the degree of protection those products are given in the developed countries. These industrialized countries are the dominant actors in most agricultural trade.

These are two dimensions of the direct external effects of farm policy in industrial countries: depressing effects on world prices and higher instability in prices. Indirectly, the threat of production is an important deterrent to the opening of LDC

economies. The current levels of protection and the unilateral and unpredictable nature of access to industrial-country markets affects the willingness of policymakers and producers in LDCs to assume the risks associated with a more trade-oriented strategy. The outcome is often an inward looking trade policy, at the cost of economic growth for most LDCs.

Developed country trade restrictions include both tariffs and nontariff barriers, which vary considerably in severity among countries and products. They tend to lower world prices by artificially reducing domestic consumption and raising domestic production in developed countries. As a consequence, the volume of exports form both LDCs and developed countries are reduced. Price and volume effects together could translate into a foreign exchange and welfare loss to LDCs. On the other hand, as importers of cereals, milk powder, and others, some LDCs have benefited form trade restrictions in these products in developed countries, as protection has led to lower prices.

Some of the effects of developed country agricultural policies on world market prices, export earnings, and import costs, and consequent welfare costs and losses have been studied by IFPRI (Valdes 1982). The results of a hypothetical 50 percent reduction across-the-board in tariffs and other trade barriers for 99 commodities in 17 developed countries belonging to the OECD indicate that LDCs' annual export revenue would have increased by $6 billion in 1985 prices (Table 1). This increase in export revenues represents an 11 percent increase for LDCs as a whole and an 8.5 percent increase for low-income countries taken separately. These figures were computed using 1977-79

levels of protection and trade flows. Trade flows and OECD protection have increased since 1977-79, so that the benefits of liberalization would be substantially greater in 1985. A recent update of the study using 1879-81 levels of protection and trade flows, but restricted to sugar, beef, wheat, and maize, concluded that export revenues for LDCs as a whole would increase by approximately U.S. $10 billion per year from removal of protection in OECD countries in those four products.

On the imports side, the increase in LDCs' imports' costs on cereals from trade liberalization and OECD countries would be substantial--on the order of at least $1.3 billion per year for all LDCs.

The analysis concludes that the forthcoming GATT negotiations offer a unique opportunity for greater integration of LDCs into the trading system under clearer and fairer rules. To take advantage of this it is suggested that in view of the importance of non-tariff barriers, they should aim for a reduction of protection, especially of domestic prices in OECD countries; a strengthening of GATT rules, discipline, and surveillance procedures; and a willingness to accept reciprocity, including trade concessions in industrial products and lifting import restrictions, within an improved international trading framework. To achieve the potential benefits of agricultural trade liberalization by LDCs will also imply less restrictive practises within their own economies, including discriminatory pricing practises of government marketing boards, regressive taxes on exports, revaluation of out-of-line exchange rates, and avoidance of using agriculture as a source of finance for

protected capital-intensive industries. IFPRI has shown that removal of trade policy-induced domestic price distortions can result in a significant rise in rural incomes (Bautista).

vi. Greater regional integration of food markets could increase security and sustainability.

Regional integration of food markets through trade can be a means of improving food security in LDCs by stabilizing domestic consumption. Instability in consumption is one of the major measures of food insecurity and, particularly in Sub-Saharan Africa, instability in cereal production is closely related to instability in production. But fluctuations in cereal production are greater on the national than on the regional level. In the case of the Southern African Development Coordination Conference (SADCC) countries, the instability index for the region was 9 percent for the period 1960-80, but as high as 68 percent for individual countries. Koester (1982) has calculated that the SADCC countries could save as much as U.S. $67.8 million or 42 percent of corresponding import costs if they were to stabilize their food import bill at a regional instead of national level. This could be accomplished by regional stockpiling schemes or by strengthening trade with each other.

- Regional stockpiling will result in savings in storage costs if instability in production for a group of countries is smaller than for individual countries.
- Regional integration of food markets could also mean less restrictions on border trade, which could contribute to improved food security in three ways. First, trade flows

could compensate for fluctuations in national production and, thus, could help stabilize consumption at the national and regional levels. Second, regional trade flows could substitute for national stockholding and in specific cases for overseas trade, which would result in higher income in the countries. Lastly, regional trade is a prerequisite for adjusting the production pattern within a region to produce to produce a comparative advantage. Considerable savings in transport costs from intra-regional trade can also be demonstrated, as well as positive allocative effects through specialization both in production and processing, through locational efficiency and economies of scale.

Integrating food markets regionally can result in high benefits, but it is not easy to exploit the potential for three reasons:

1. Reducing or abolishing trade barriers will make it necessary for individual countries to give up some of their autonomy in determining their food policy.
2. Countries will have to develop an institutional framework, especially if they start joint actions, like regional stockpiling, which guarantees that benefits are evenly spread and cost sharing corresponds to expected benefits.
3. A full integration of regional food markets can only function if countries solve their foreign exchange problems. It is not likely that countries will be able to provide all of the prerequisites,but they may be well advised to start with joint actions, like regional

stockpiling and trade agreements that allow for trade at international prices.

vii. The role of taxation in providing sustainability.

Many developing countries have a weak tax base, and they compound their fiscal problems by regressive taxes which bear most heavily on agriculture. Of course, in a predominantly agricultural economy, it is unavoidable that the agricultural sector will be taxed. However, instead of export taxes and tariffs that distort relative production incentives, some more efficient means of taxation should be used. Land, income, and consumptions taxes seem the most appropriate. Under agriculture- and employment-based development strategy, such revenues from agricultural taxation would finance needed public investments in the rural areas in order to raise farm productivity and foster the development of rural industries.

While these revenues would help to achieve the goals of sustainability if used for productive investments of the type outlined above; it may also be worth using taxation or other fiscal measures more directly as an instrument of policy, for example, to provide an incentive to sound land use, or to discourage actions by individuals or social groups which lead to resource degradation. Possibilities include:

- Purchase of land by the state and renting it to users under supervised management for forestry, grazing, irrigation, or land settlement. Privatisation of common lands has been advocated (for example by Hardin), but has not always led to better range management. The right to revoke leases may be

a necessary part of such policies, but is also open to abuse.

- Licensing individuals to develop certain resources e.g. fuel wood collection and charcoal burning or fishing rights in remote areas such arrangements are difficult to monitor.
- 'Head taxes' on livestock numbers. These are difficult to assess fairly in relation to stocking capacity for sound grazing management in free range areas, as well as to monitor and collect. Remission of taxes with respect to mothered or stall-fed animals may encourage reduction in numbers on the range. Taxes on tree felling in forests or woodlots which can be inventoried are probably easier to administer and more effective. They can be used to finance reforestation. Exploitation of tropical forests by commercial entrepreneurs who extract timber and move one, without regard to the future of the resource should be treated ruthlessly by governments. Demand for tropical timber is high and there should be no difficulty in developing partnership arrangements with responsible commercial companies, which will provide revenue from taxes on exports, manage extraction, assist with replanting, and help train local staff.
- Payment for services: veterinary, water supplies, even extension services.
- Taxes on consumptive use of water in state irrigation schemes.
- Acreage payments or other financial incentives to plant

trees, forage crops, leguminous shrubs, etc. in selected areas determined according to land capability.

- Quotas on animal numbers in marginal field hands, to prevent misallocation of certain areas to unsuitable crops or commodities in excess of market demand. Such policies require good statistical information for their successful implementation, and may be more effective if supported by action in prices and marketing. Another way of approaching the same problem is to ban production in certain areas subject to degradation; or to use discriminatory prices. Certainly they should not be subsidized in such areas as has been the case with cereals or small firms in mountain regions of Europe.
- Profit-sharing arrangements between state or local authorities and indigenous people designed to maintain sustainability. The Masaii participation in the management and profits resulting from the development of part of their tribal grazings in Kenya as a game park is one such example. Technical assistance to land owners to undertake improvements in select areas (mechanical terracing and tree planting for soil conservation) may sometimes be helpful.

Such policies can really only be designed and implemented effectively at the national and local level and with profound understanding of land capability, ownership, customary rights, and social pressures. The more drastic they are, the more likely to the more likely they are to be unpopular with some sectional interests. Thus, even if society as a whole gains, the question of who loses cannot be ignored, and action may have to be taken

to offset such losses as part of an holistic plan. It is particularly important to see that those who suffer most are not the poor.

On the demand side, it is impossible that action can be initiated through price policies to discourage the consumption of products which threaten sustainability, particularly if these are largely luxuries. In some cases, rationing may be necessary, but inflates bureaucracy and encourages black markets which cannot be produced locally. As mentioned earlier, import quotas may be imposed, although these risk trade reprisals. More difficult cases arise with imports of foodstuffs in deficit situations (wheat and coarse grains for livestock feed), or petroleum products.

viii. Restraints on population growth: a difficult but essential goal of sustainability.

Although some countries can still sustain a rapid rate of population growth, most recognize that it will be necessary to try and stabilize population within the foreseeable future. Some have adopted stringent measures to do so, through taxation, rationing and restrictions on housing and social services to large families. While there is an inverse relationship between economic growth and population growth, the effects take time to have an impact. Investment in health services, housing, clean water, and the provision of family planning guidance and facilities can help to reduce the rate of population increase through voluntary restraints, although there is a chicken-egg problem in that where current growth rates of population are

rapid, it is more difficult for poor countries to provide adequate services. It is essential that donors support such efforts rather than looking the other way.

EXECUTIVE SUMMARY

1. Goals and concepts related to sustainability

This paper is based on the assumption that the goal of a sustainable agriculture is to maintain a growth rate of agricultural production compatible with the needs of an expanding world population for food and raw materials, while minimizing environmental degradation or other destabilizing influences, whether political, socioeconomic or technological.

Sustainability is a dynamic not a static concept, it is not just conservation; therefore, we have suggested the following definition: 'Sustainability is the successful management of resources for agriculture to satisfy changing human needs'. This definition avoids imposing judgmental preconditions as to how this objective should be achieved. Nevertheless, it recognizes the importance of continuity in support to sound policies and the need to maintain the viability of institutions, programmes or projects established to implement these policies. Instability and lack of continuity of support to development programmes by donors and by national governments is an important cause of loss of sustainability.

The task of maintaining the sustainability of agriculture is seen as formidable, especially moving into the next century when world population is expected to double, and climate may be more

variable and less benign than it is at present. Moreover, many developing countries have to attain faster growth merely to catch up on lagging food production in the recent past, quite apart from meeting these new demands on their resources and technical ingenuity. One difficult issue with which the TAC will have to grapple is how far into the future it wishes to look. The paper suggests an action programme geared to the remainder of the twentieth century, with a longer contingency planning horizon of fifty years.

In noting that goals of sustainability are at the root of many of the measures devised by producers and embodied in agricultural practises over the centuries, the question is raised as to why the international development community is suddenly attaching such importance to it, and what differentiates policies related to sustainability from other concerns of development policy. These too, it is assumed, have growth with equity as a main objective. Thus, it is not easy to isolate policies designed to promote sustainability from the development process as a whole, which involves other sectors than agriculture and complex interactions.

It is suggested that perhaps the current emphasis on sustainability (which we hope is not just another fad) is motivated (a) by alarm over the breakdown of traditional producer safeguards under pressure of rapid population growth and other destabilizing influences, (b) by perceptions of high risk and helplessness associated with resource degradation and related

discontinuities, (c) by externalities both in developed countries (mainly due to industrial pollution), and in developing countries (due to environmental stress). These make the future potential more difficult and probably more costly to realize, (d) inadequate understanding of the processes and institutional measures by which some of these problems might be alleviated, due in part to poor information and monitoring of ongoing changes, and (e) uncertainties as to how far new technology, the nature of which may yet be only dimly perceived will provide solutions to some of these problems without aggravating others. A conclusion is that it is important though not easy, to take careful account of spatial and temporal variability, technological change, externalities, and interactions, in attempting to indicate policies which will promote sustainability. Thus, it has proved difficult to find a half-way house between a short issues paper and treating the subject in-depth.

Strategic Options

Since it is unlikely that any 'one-world' solution involving a pooling of global resources is feasible, and three strategic options are suggested to achieve goals of sustainability. These are:

- To discount the future heavily against the present, even if this means exhausting some resources and depriving future generations of their use. The basic assumption here is that solutions over the longer-run will be provided by the

continuing evolution of new technology, as has occurred increasingly in much of the world during the last fifty years.

- To follow a strictly conservative approach, which seeks to achieve balanced growth by husbanding resources and preventing any further degradation of the environment by prudent management, while reclaiming degraded areas for productive use wherever feasible. This may impose penalties on existing populations for the sake of the long-term future.

- To develop greater complementarities and cooperation between international actions and national efforts as a means of managing the global environment more effectively for higher productivity, allowing for more intensive use of technology in high potential areas, (even resource mining); thus reducing environmental damage indirectly by decreasing pressures to produce food or to maintain larger populations in fragile ecological situations.

A key issue in the first two of these options is how much we attempt to extract from a given resource to meet current or immediately foreseeable needs, and how much we attempt to preserve for posterity. Both approaches entail risks: the first that technology will not be adequate to sustain high growth even in favorable areas, the second that policies geared to resource conservation will neither succeed in preserving resources under

pressure nor in increasing output fast enough through low-cost technology. The third, middle of the road, approach involves greater cooperation and rationality in relations between countries, which implies some faith in human nature, and reliance on acceptance of improved institutional mechanisms which may be hard to devise. The choice among these options depends heavily on the assumptions made concerning major areas of uncertainty. These include:

- The nature and rapidity of climatic change, and its geographical impact.

- The state of depletion or degradation of resources already in use, and the costs of their improvement or reclamation for sustained use versus more rapid exploitation, or even exhaustion.

- The availability of new land and water resources for agriculture, their quality and the cost of their development.

- The continuity of technological progress as an engine of agricultural growth.

- The rate and distribution of population growth.

- The success in building and maintaining effective institutions as instruments of policy.

- Progress towards a more rational structure of international north-south cooperation.

These are the issues on which the remainder of the paper focuses.

2. Major climatic influences affecting sustainability

Until recently, climate has been the main natural resource determining the geographical distribution of crops and ruminant livestock, as well as the absolute levels of mean yields. Even today, despite the pervasive influence of modern agricultural technology in the industrialized countries, and its growing importance in the developing countries; there are large areas of the world, especially in Sub-Saharan Africa and tropical South America, where climate remains the dominant factor. Thus, its importance in the context of sustainability is paramount. Many of the traditional practises of agriculture are attempts to avoid or mitigate climatic risks. A number of these practises are becoming hard to sustain under pressures of climate, urbanization, population, or a lack of suitable technology. Four categories of climatic influence are identified. These are:

i) Emergencies caused by short-term climatic shocks (typhoons, hurricanes, floods).

ii) Interannual climatic variability. The most widespread and important influence on agriculture.

iii) Climatic anomalies extending over a considerable period (e.g. since 1970 in Sahelian West Africa).

iv) Long-term climatic change. This may be adverse or favorable to sustainability. It has largely been taken as a constant by planners, but recent indications of a long-term warning trend due to anthropogenic influences, possibly accompanied by changes in interregional distribution of precipitation and increased variability, suggest that it would be unwise to continue to do so, especially in relation to long-term investments for land and water, settlement policy or agricultural research.

Identification of high-risk areas

It is suggested that policies and related actions to improve sustainability and reduce risks arising from climatic events should be classified in terms of these four categories. This offers two advantages: first, it provides a time-phased sequence for planning purposes; secondly, it enables policies to be related to specific geoclimatic regions, since the areas principally affected by each of these four types of influence are not the same, nor are the risks. Thus category i) countries, mainly in the wetter tropics of Asia, the Pacific, and the Caribbean are at high risk from short-term climatic emergencies, but have relatively low interannual variability. Category ii) countries, mainly near the drier and colder margins of agriculture have high variability, but are less prone to sudden violent shocks. However, especially in the semi-arid tropics, there are large numbers of low-income people and a shortage of suitable technology so that they tend to be more vulnerable to a variable climate than people at the colder margins. Category iii) may be difficult to differentiate from normal variability until enough years have elapsed to confirm a trend, and if it is adverse, irreparable damage may have been done since deterioration tends to be cumulative over time. Whether any action (irrigation or resettlement for example) is merited to try and counter such a situation depends on its severity, the location, population density, and the options open.

Category iv climatic warming effects are likely to be most dramatic in high latitudes and lowest in equatorial regions, although coastal lowlands in the latter might suffer increased risk of flooding if sea levels rise due to ice melt.

The impact on precipitation is more speculative, but there seems to be a more considerable measure of agreement that the U.S. Corn Belt is likely to become drier as well as warmer, pushing the optimum climatic zone for corn production further north. This, however, would probably extend into an areas of podzolic soils, hence yields might fall. Because of the present high dependence of the majority of food deficit countries on grain reserves from mid-latitude temperate countries, particularly the United States, any long-term climatic threat to the sustainability of grain production in those countries is of the utmost gravity. Thus, the regional priorities for research and other international food security to counter climatic change may be different from those to deal with shorter-term climatic hazards, especially those related to high interannual variability.

Policies to reduce vulnerability to climatic hazards

In any of the four situations described above, improved weather forecasting and tracking of trends in order to provide early warning of the nature, direction, and magnitude of climatic shocks, is likely to be beneficial. Timely warning is particularly valuable in the case of sudden emergencies. The policies are likely to involve measures to conserve emergency food supplies, maintain medical, power, and other vital services, prevent civil disorders, and perhaps to introduce and enforce evacuation and other controls on movement. Agriculturally, little can usually be done until the actual emergency is over, although future losses might be reduced by shelter belts and changes in cropping patterns and location of crops.

High climatic variability is often difficult to distinguish in the short term from intermediate medium-term climatic anomalies and the policies required to sustain agricultural production where they are prevalent are not dissimilar. They include in the shorter term:

- Food security (strategically sited reserve stocks, infrastructural improvement; food imports);

- Food-for-work programs, based where possible on food aid, directed to reducing climatic risks (infrastructure, irrigation).

- Research to improve stress tolerance in plants or animals; soil and water conservation; low-cost measures to increase soil fertility, reduce erosion, and control weeds;

- Improvement and diversification of seed production services to increase flexibility or promote changes in cropping patterns where desirable.

- Development of water resources, both for drinking purposes and for irrigation.

- Introduction of fiscal and other economic measures which provide incentives to innovate even in higher risk areas, as well as offering some insurance of relief for situations where weather adversity threatens sustainability of production or life itself. This may be vital for pastoralists, since livestock prices tend to fall and grain prices rise in drought situations.

- Resettlement, perhaps as a last resort.

Some policies are easier to implement in an emergency than others, but some (whether easy to introduce or not) are difficult to reverse once the emergency is over,and some are virtually irreversible. When planning a set of policies to deal with contingencies involving different time horizons, and degrees of certainty as to their occurrence, such as those posed by climatic

variability and climatic change, decision-makers face a considerable problem of balancing too much too soon against too little too late! Deciding what must be implemented to provide an immediate but perhaps minimal level of food security, what should be done over the longer term anyway as part of a prudent policy to provide a more secure and sustainable agricultural base, and what might have to be done in time should climate deteriorate, involves delicate judgment as to what plans to put into operation and what to leave on the shelf.

From the point of view of sustaining agricultural development, it is questionable whether specific action other than enhanced research in climatology and agroclimatology is merited before the year 2000 with respect to climatic change. What is required is closer monitoring and evaluation of key climatic parameters, accompanied by improved characterization of agro-ecological zones, current land use, and levels of resource degradation in those zones. Thus, any changes in climate, as well as increases in variability or frequency of anomalies or storm intensities could be identified sooner and their intra- and inter-country impact assessed.

The cost of reinforced international monitoring, research, and evaluation of climatic data and its implications for a sustainable agriculture; which inter alia implies a substantial strengthening of meteorological data-gathering and analytical capacity in developing countries, may be considerable in absolute terms. It is nevertheless likely to be very small in relation to

the precision it could eventually provide to development policy in a changing world.

3. Land resources and their management for sustainability.

Both as the basic resource for agricultural production and because of its value as a commodity, land has enormous economic, social, and psychological importance. This has resulted in intense competition and conflict over its use. The report identifies a number of destabilizing causes and consequences of these pressures. They include:

- Widespread overgrazing of rangelands, threatening biomass degradation and possibly affecting climate in semi-arid and mountain regions.

- Deforestation in a wide range of environments but particularly damaging in tropical rain forests because of catastrophic erosion of soil, genetic resources, and a possible but as yet inconclusive impact on world climate.

- Problems of common land affecting use of both grazings and forests, and posing difficult social as well as technical obstacles to improved management of the resource.

- Technological change, principally through effects on the maintenance of soil fertility, organic matter content, structure, and moisture absorption. Mechanization is

probably the most controversial technical factor involved; not only in crop production but less directly in overgrazing and deforestation.

- Chemical soil and water pollutants (fertilizer, pesticides, detergents) are only now becoming significant in a few developing countries; in industrialized countries both those and air pollution are already having serious environmental impacts.

- Urbanization is likely to make increasing inroads into agricultural land with rapid population growth in Third World countries.

- Human pressures, in particular the inexorable spread of cultivation to marginal grazing or forest areas without inputs or other measures which might make their use for crops sustainable. Population growth, inequitable access to land and production inputs, lack of technical knowledge, and poverty are the driving forces to seek new areas.

Major policy issues requiring research identified in the report are:

- How important economically is land degradation.

If policy-makers, internationally or nationally, are to be expected to treat such losses seriously, and especially

if they are to take costly and possibly unpopular action to reduce or control them; then they must be presented sound and unbiased information relevant to the situation in their own jurisdiction. There is a poverty of hard data on many of these matters, statistics are conflicting, definitions ambiguous, and costs hard to identify.

- How important economically is land degradation?

There is a poverty of hard facts and data on the causes and magnitudes of various losses due to environmental deterioration, their economical and social value, and the costs and benefits of attempting to minimize them. There are huge gaps and obvious inaccuracies. Sometimes the statistics are conflicting, while definitions are often ambiguous and open to misinterpretation. Reliable cost estimate of losses are hard to come by. More research is needed to provide these facts, and to relate them to specific land use patterns identified eco-climatic or agricultural parameters, and elements of risk. The CGIAR has not so far shown much interest in such issues. Perhaps it should reinforce ongoing work on agro-ecological characterization and resource classification so as to illuminate such issues, even at the expense of breeding programs.

- How detrimental is rapid population growth to sustainability.

While rapid population increase is held by most authorities to be a root cause of poverty, environmental degradation, and declining levels of sustainability; others argue that the effects are not wholly bad, providing extra labor for poor families and acting as a stimulant to the adoption of more intensive methods of farming. The problem may not be the rate of population growth per se, but what absolute level is sustainable over time within the bounds of reasonable expectations of technical change. The issue merits unprejudiced inter-disciplinary research; since it is highly charged with religious and other emotional content.

- Is production of agricultural commodities for sale inimical to sustainability?

Food security does not imply food self-sufficiency at all costs: trade can play an important role. Nevertheless, 'food first' advocates assert that production for sale decreases food security. IFPRI research in Africa and Latin America shows no overall ill effects of sole either food or non-food crops on family incomes or nutrition but this seems to be an issue of concern to some CGIAR members which probably merits further research.

- What are the effects of unequal access to land on sustainability?

The size distribution holdings varies greatly within countries. The location as well as the size of a holding,and whether owned or tenanted, in relation to climate, soil quality, water, roads and markets, critically determines both land values and rents. If unequal access to land is a serious cause of degradation, what technical or other measures can be taken to offset this?

- Should priority be given to developing areas of high yield potential, or to finding solutions to increasing output from resource-poor areas?

Probably, the ideal answer is 'both', but given resource constraints, many development strategists urge that to give priority to high potential areas is a more efficient way of using scarce finance, inputs, technical, and managerial skills. It is also argued that this will provide employment and other opportunities, which lessen pressure in resource-poor areas. However, this raises difficult issues of equity and polarization, particularly of more remote areas where lack of suitable technological support may lead to severe hardship and degradation. Clearly, this is a research issue of high priority and relevance to CGIAR policy.

- Which areas should be monitored for, and have sustainability?

A question mark must be placed against the value of a high technology potential area focus in learning more about

the human and biotechnical factors determining sustainability, especially if deterioration is occurring largely in more marginal or remote areas, some of which may not yet be fully developed agriculturally. Little serious attention seems to have been focused on methods and mechanisms for monitoring or evaluation of land use in relation to sustainability. It is an issue which merits more international or national cooperation, both for training and in its implementation.

- How can local people participate in land use planning?

If conflicts of the type described in this chapter are to be avoided in the future; and if, as many authorities urge, incentives are to be provided to people of an area to act responsibly for the common good in the use and management of their resource; then elected local people must be given a chance to become involved in the planning and implementation of their own land use policy. This should complement scarce institutional resources and increase success rates in rural development projects. 'People involvement' in a land use plan, is an endeavor which requires inter-disciplinary cooperation, and which seems not have had the attention it merits in research programs. We urge that it is given higher priority.

- What questions need to be covered in formulating land use plans?

As a basis for policy decisions as to what action to take to ensure sustainability, it is necessary to be able to place land use and land degradation in the context of a specific cause-and-effect situation, to be able to assess the costs and benefits of remedial action more precisely, compare them with other opportunities for productive use of the resources of the area under study.

The paper defines the questions which need to be addressed in the formulation of land use plans, and suggests that a central objective of such plans should be to identify three types of development potential. These are:

i) High potential areas: suited to intensive agriculture and having a high population support capacity.

ii) Stabilization areas: suited to cropping or their agricultural use with appropriate safeguards and to conservative rather than intensive production systems.

iii) Conservation areas: where cultivation should be restricted and grazing or fuel-gathering might need to be limited and monitored. Such areas would normally receive low investment priority, except where a reclamation potential was identified or to prevent dangerous externalities.

4. Sustainability in irrigated agriculture.

Three problem areas are discussed:

- Past growth in irrigation has come largely through area expansion. A second possibility, more intensive use of existing irrigated areas, is impeded by competition from other uses. Irrigation systems will thus be called upon with increasing frequency to sustain growth in production with a fixed or even a declining water resource. This raises serious questions about the sustainability of past growth rates of irrigated production, tools and mechanisms which blend (1) physical improvements, (2) changes in management structures and practices, and (3) policies governing the subsector are available to accomplish this; however, results have been uneven. Although experiments applying differing combinations of these factors have been undertaken, there is not yet a clear understanding of or agreement on the sets of measures which are most appropriate in particular settings, or on the magnitude of their impacts.

- Self-sustaining systems

Along with the expansion in irrigated areas in most countries, has come a rising recurrent cost burden on national or state treasuries. This is so because in the

vast majority of cases, recurrent costs are not funded from irrigation revenues, which are inadequate in any case, but form the general revenues of the state. Moreover, water is paid for by its users on an administratively-determined basis that usually bears no direct relationship to the quantity of water used. To break out of this cycle, it is necessary to reassess the basis on which irrigation agencies operate, raise their revenues, assess their institutional performance, reward and promote their staff, and share responsibility with farmers. This is a most important area for further research affecting the sustainability of the function of the systems.

In a larger sense, irrigation agencies must develop the capacity to manage the adaptive change process itself. One sure companion to economic develop is the increasing pace of change. Irrigation systems designed 50 or even 15 years ago are today typically called upon to perform different functions and satisfy different objectives than those they were designed for. From a longer-range perspective, therefore, the fundamental "solution" to the problem of sustainability is the development of a set of institutions which work together to provide the capacity to deal with change. These must include the irrigation agency, farmers, and supporting organizations.

- Irrigation and the resource base

In the best circumstances, irrigation development captures and puts to productive use a renewable resource of enormous potential benefit which would otherwise have little economic utility. Indeed, the food security of many nations depends critically on the productivity of their irrigated lands. Their sustainability may be threatened both by externalities caused by related systems of land use in upstream watersheds (see Chapter 3), and by negative externalities of irrigation systems themselves on people in the area and on the resource base. Their avoidance entails complex socio-technical problems which so defied easy solution. Of all of the undesired consequences of large-scale irrigation development, salinity and waterlogging are probably the ones most frequently mentioned in the context of long-run irrigation system sustainability. In some situations, there is no alternative to the installation of extensive surface or tile drainage systems in previously irrigated areas. In other cases though, and as a complement to the installation of drainage systems, are a number of non-structural measures which can have a significant impact on alleviating problems of waterlogging and salinization.

To the extent that W&S problems stem from over-irrigation, measures that reduce the incentive to use more water than necessary also alleviate W&S problems. Additionally, system which transfer at least a share of the costs of treating the problems to those whose actions

influence their creation can also be effective. The search for ways to stimulate private investment in water table control and other non-structural ways of dealing with resultant W&S problems deserves much more attention than it is currently receiving.

5. Technology and sustainability

The report notes the tremendous progress that has been made in agricultural production during the last fifty years, both in the industrialized countries and in the developing world, except for Africa. This progress has been due to an increasing extent to higher yields as a result of technological advances, especially where input-output price ratios were favorable, and other support services and infrastructure satisfactory. In some instances, food surpluses have arisen, either where demand for food is inelastic, as in Europe, or where purchasing power is low, as in Asia. In Africa, by contrast, the constraint is on supply rather than on demand.

A cautionary note is sounded concerning preconceived notions as to what technology is good, bad, or 'appropriate'. Technology needs to be tailored to specific situations, which vary both within and between countries. Four situations can be identified according to relative scarcity or abundance of land and labor i.e. i) land abundant; labor abundant; ii) land abundant; labor scarce; iii) land scarce; labor abundant; iv) land scare; labor scarce. These are not immutable over time; thus, Japan has moved

from iii) to iv),and is using labor as well as land-saving approaches; the United States has increasingly turned towards yield-increasing technology, which is often thought of as land saving, despite its relative abundance of land. Thus, it is most important for research and other institutions involved in the generation and diffusion of new agricultural technological to be flexible in meeting changing and social and marked needs and changes in relative factor scarcity.

A basic assumption of the report is that technology will contribute increasingly to sustainability of agriculture, and that great scope remains for it to do so, especially in developing countries where yields on average are so low. However, it will be necessary to build in safeguards to ensure against environmental degradation, drawing on past experiences in countries further along the technological road. Attention is drawn to the relative lack of success in finding technological solutions to improving ruminant livestock production, generally and especially to reducing damage from overgrazing in semi-arid rangelands. Similarly, little progress has been made with respect to the fuelwood problem, either directly, or through developing low-cost alternatives. Thus, important challenges remain.

The following policy issues are selected as being of special significance:

- How can fertilizer use be increased, especially in higher potential areas?

A vast increase in the use of chemical fertilizers is generally considered essential to generate and sustain yield-based growth in agriculture. The report identifies a number of objectives for designing a sound fertilizer policy, as well as research-based policies in five directions, without which rapid growth in fertilizer use cannot be sustained. The latter includes: i) those which lower farmers' cost of fertilizers through removing numerous deficiencies in fertilizer production, imports and distribution, as well as agricultural credit systems to help both in distribution, and purchase by farmers, (ii) those which identify and facilitate the use of natural fertilizer sources in developing countries: rock phosphate, gypsum, guano, etc., (iii) those which improve responses of crops to fertilizer use and improve efficiency of use by strengthening agricultural research and extension systems and the interface between them; (iv) those which develop efficient agricultural marketing and processing systems and thus raise farmers' share in consumers' price of their produce, (v) studies of appropriate fertilizer pricing policies in relation to their delivered cost and producer returns in output valued at market prices.

- What should be the place of mechanization and chemical tillage and weed control practices in sustaining agricultural production?

From the point of view of sustainability, the problem is not simply one of poor operating and maintenance techniques leading to high running costs and machinery "graveyards, (although this has been a prime source of failure), but of learning how and when to till and cultivate crops to prevent excessive runoff and loss of structure. There are difficult research tasks in devising and testing conservation practices as well as in finding the optimum combinations of power (whether draft or mechanical) and equipment for specific operations, soils, and seasons. Successful adoption of research results may depend on availability of cheap equipment and cooperation among farmers in implementation, as in watershed management. Substitution of animal draft for mechanical power may not solve these problems; moreover, in much of Africa, its use is constrained by tse-tse infestation.

'No-tillage' approaches to land preparation and herbicides for weed control seem to merit more research as alternatives to power tillage; although more scale-neutral, they are not without risks and do not offer the advantages of machines for transport or marketing.

- What technology is sustainable in "resource-poor" areas?

A good deal has been written in recent years concerning the need for low-cost and/or low-input technologies which will enable production to be maintained and possibly increased without environmental degradation in high-risk areas or those unsuited to intensive agriculture. For such areas, the report suggests a number of integrated measures to increase stress tolerance, maintain soil fertility, and reduce pest, disease, and week losses.

However, it stresses that all of these concepts may not be applicable everywhere, and that because some are novel, their success will depend heavily on good communication between farmers and extension staff as well as on flexible seed and other supply services.

- Has relative variability increased as a result of yield-increasing technology?

Reports from some industrialized countries, as well as from Asian developing countries suggests that this may be the case; due to: i) use of varieties with a narrow genetic base over wide areas; ii) fluctuations in input supply to producers; and, iii) inadequate or improper input use by producers.

The impact could have serious implications for sustainability, but the evidence is somewhat conflicting. Other studies suggest that over longer time periods, the problems caused by ii) and iii) above tend to lessen as experience is gained by suppliers or uses. The first threat remains, and valuable lessons to be learned from these studies with respect to research policy, the dangers of the large seed-chemical companies dominating breeding programs, and the crucial role of efficient input supply and information services in the successful adoption by producers of new technological approaches.

- <u>What can be done to prevent deterioration of grazing resources in semi-arid areas</u>?

This is a most difficult issue, as will be clear from our earlier observations. Many attempts have been made to find solutions, but few have had really lasting success. After discussing these, the reports argues that the aim of ruminant livestock policy in Africa should be to promote conjunctions of interest and maximize complementary ecological zones with different potential for rearing and fattening, and between herding, settled farming, and planting of trees for fuel and fodder, rather than the destructive competition that has so often been the rule in the past because the externalities rather than the complementarities have been dominant. A number of priority

areas for research and action is indicated directed to these objectives.

National policies are required to reconcile these potential conflicts, and in most countries these imply a drastic rethinking of support to the livestock sector including price structures, infrastructure, institutional support and marketing facilities commensurate wit its social significance and economic potential.

6. Human Influences on sustainability and their management: The growing impact on human activities on the global environment.

The report draws attention to the massive and increasing impact of human activities on climate, vegetation, soil fertility, water supply and quality, and other renewable and non-renewable resources. It notes that the rate and complexity of change in the global environment in the present century as a result of the growth of human population, the expansion of agriculture to new regions, the development of new agricultural technology, industrialization, dependence on fossil fuels for energy, and the spread of vast urban connurbations, has exceeded anything in previous history.

In many ways, these changes and their rapidity make sustainability more difficult to achieve; especially in agriculture, because of its ecological and geographical diversity

and the vast numbers of people it employs, often with conflicting aims. Because the constraints they face are often outside their control, help in managing their resources has to come from measures devised by governments, sometimes with international assistance. Thus, the stability of the policies from which these measures are derived, and the support provided to the institutions through which the polices have to be implemented, and knowledge and resources channeled to producers is crucial to the success of their efforts to achieve sustainable production.

Major institutional issues affecting sustainability.

Political instability is extremely inimical to sustainability; leading to discontinuities and inconsistencies in policy, disruptive changes in staff, and sometimes to a breakdown in law and order. The report stresses the need to devise mechanisms of government which will promote continuity of sound and generally accepted policies even when ruling parties or heads of state change.

Gaps in mechanisms for policy formulation are a source of unrealistic plans and resource allocations which are inconsistent with plan targets. Such gaps are particularly prevalent between economic or finance ministries, which tend to be weakly staffed in social sciences. Serious communication gaps also exist between central policy staff and heads of services within line ministries; and between heads of services, resulting in lack of

coordination in planning. Little or no provision is generally made for participation of the private sector in plan formulation.

Fragmentation of responsibility for agricultural development, especially research and extension, among numerous ministries is common, and a serious source of poor planning, coordination of action, and service to producers. The report reviews some of the mechanisms which have been devised to try and remedy this situation.

Continuity of funding is essential. It is noted that in some cases, development assistance agencies differ as to the optimum institutional approaches although generally agreeing on the need for political commitment to their support, on the need to channel more funds to agricultural research, and on the importance of providing adequate funds for recurrent operational support to increasing number of trained national staff.

While in accord with these comments, the report states that to some extent, a proliferation of donor support especially to research has contributed to the recurrent expenditure problem, because national governments are encouraged to take on commitments they are eventually unable to sustain from their own resources. Instability of donor policies and financial commitments contributes to instability in national systems.

Horizontal linkages between government services are often week. This is done particularly of research and extension, and

the report examines a number of policy solutions, including inter-service councils, linkage mechanisms and mergers. It concludes that no ideal solution has been found, and that there is a need for drastic rethinking of approaches and methods, as well as possibly for some additional support to technology transfer mechanisms and for research and evaluation of their operations, as opposed to 'research on research'. No CGIAR institute has direct responsibility for technology transfer, few research evaluation missions take a serious look at the inter-service adn institutional linkages; thus, an opportunity for learning more about problems of two-way communication between researchers and producers is being lost. This gap is to some extent being narrowed by farming systems and on-farm research, but the latter is a burden on smaller national systems. Its conduct and support leaves much to be desired, and the methodology is still evolving.

The report raises a number of questions on approaches to on-station, on-favor and featuring systems research as well as on the ideology of extension with respect to the use of modern communications technology, for contracts with producers, and the provision of inputs.

The involvement of producers in the planning and implementation of government-agricultural development is generally small, and frequently non-existent.

Many studies of the factors conducive to sustainability argue that failures to achieve lasting benefits from rural development efforts are frequently caused by top-down planning and lack of involvement of the potential beneficiaries in the formulation of the plans or in their management. The need for local people to be brought into this process very early is frequently being stressed, especially with respect to issues affecting resource degradation.

At the same time involving people initially is not easy. Historically, they are often not used to invovlement and consultation; therefore, their attitude may be passive or even suspicious. Questions of individual or sectional interest versus society can cause feelings to run high. Thus, a careful process of social science action research may be needed before the factors hampering participation can be identified, priorities established and firm plans formulated and implemented.

Issues which need to be addressed with respect to participatory action include:

i) How can local people be involved to complement formal expertise in plan formulation?

ii) In what operational format can they participate in the implementation of plans for their region?

iii) What supporting services and funds are required to make their participation self-sustaining?

To achieve success may require modification of conventional plan formulation and institutional structures; but we believe the effort would be rewarding. Evaluation of case studies of successful intitatives could help to provide answers.

What does education contribute to sustainability?

Economic evaluation of returns to education indicate that farmer education leads to more effective use of technology; moreover, that larger benefits accrue to investment in primary than to higher education, especially that of university-level. This has sometimes been used as an argument against donor support of investment in higher education and training in developing countries, on the grounds that it does not benefit the poor.

We do not feel that this is an 'either-or' situation: both general and higher education are valuable. Some questions that need to be studied include:

- How greater equity can be achieved in primary education, so that socially or economically disadvantaged groups have equal opportunities?

- What proportion of the education curriculum in rural areas

should be devoted to vocational aspects of rural life, and what to general education?

- How can older people in rural areas be given access to basic learning skills so that they can make better use of knowledge and services?

- How can universities contribute more effectively to the identification and achievement of national agricultural research priorities? This aspect of education seems to merit greater attention by the TAC, the CGIAR, and by research review missions.

Infrastructure as an aid to sustainability.

Although roads have been blamed for accelerating degradation of forests and pastures in some areas by providing easier access to remote areas at high economic and social cost; there is a lot of evidence indicating that their role is strongly positive in many respects. These include:

- Facilitating regional, FSR, and OFR to develop more suitable agricultural technology.

- Providing better advisory and credit services to producers and facilitating their more frequent use.

- Providing easier access to inputs.

- Reducing market costs.

- Opening up new on and off farm employment opportunities and inter-sectoral linkages.

- Raising the quality of life, increasing rural incomes, and improving health and food security.

- Increasing competitive power on export markets.

Much of this evidence is derived from recent IFPRI studies, and both within regions of a country and by comparisons between Asian countries, where infrastructure is generally fairly adequate, to African ones where it is often poor. The resulting differences in favor of areas with adequate infrastructure are extremely striking.

The report indicates the need for additional research on some aspects of infrastructure, especially those related to the optimum ratio of main to feeder and all-weather to other roads in varying situations of high and low potential complementarities between various modes of transport, location of rural services, and questions related to funding of recurrent costs of maintaining roads, vehicles, and other rural services.

7. Macroeconomic policies and their influence.

The impact of the macro-economic environment on sustainability.

Many studies emphasize the interdependence between investment in research, the demand for and the adoption of new agricultural technologies, and the national political and economic environment. The latter, in turn, is subject to external economic pressures over which an individual government may have only limited control; including, in particular, policies of developed countries with respect to trade and foreign aid. Thus, at the national level, both the external economic environment and internal differences need to be taken into account in developing a coherent land-use and technology policy. Innovations are sensitive to the economic environment, just as much as the agroclimatic and soils environment.

The report discusses the evolution of macroeconomic policies in a number of regions and stresses the importance of stable government and continuity in domestic and foreign policy to sustainability. The dangers of over-reliance on public institutions such as State Marketing Boards are stressed, especially where these exert excessive control which discriminates against the private sector, act as vehicles for penal taxation of agricultural exports, and divert a high proportion of trained staff and capital from programs which increase production. Some of the causes of failure of state and para-state enterprises are discussed, and it is noted that many

countries are moving away from massive state control and exploring other institutional modes. This is an area in which more research and case studies of successful experiments is likely to be rewarding.

Measures and policies to promote sustainable agriculture.

The report identifies a number of areas of macroeconomic policy in which appropriate measures would increase sustainability. These include:

i) Avoidance of over-valued currencies which can lead to serious price distortions which adversely affect both domestic agricultural prices and agricultural export earnings; and favor urban consumers by facilitating cheaper imports, both of food and luxury consumer items. They also favor capital-intensive domestic industries over labor-intensive ones, thus reducing employment opportunities.

ii) Avoidance of large abrupt changes in macro-economic policy.

These can be counter-productive by causing serious political unrest; at best, they are difficult to absorb without destabilizing effects on the economy. The issue is how to achieve the objectives of policy without running avoidable risks. Measures which may be unpopular with large or politically powerful segments of society must either be phased in gradually, or else accompanied by social or fiscal measures to mitigate adverse effects on at least some of those who lose as a result.

iii) Macro-economic policies must themselves be sustainable.

This is particularly important in the case of subsidized input and credit schemes which are relatively easy to introduce but which are often difficult to administer and incur financial losses which impose an unsustainable burden on the economy. If they have to be abandoned, political unrest sometimes follows.

iv) Employment growth provides incentives to increase food production without depressing prices.

Analysis of time series data on poverty and agriculture over one or two decades shows the two most powerful forces determining poverty to be per capita growth in food production and change in food prices. The first is a major determinant of the amount of employment. The second determines the purchasing power of a given level of income. Employment growth raises demand for food, since a high proportion of income in developing countries is spent on food. Thus, to reduce poverty, the ideal is to increase food production and to lower food prices by reducing the cost of production through technological change. To avoid lower food prices eventually becoming a disincentive to producers, the answer is to stimulate sufficient employment growth in the nonagricultural sector to increase demand for food by as much or more than the increase in supply. It is the link between agricultural growth and labor-intensive

nonagricultural growth that needs to be encouraged and that offers so much potential for concurrently increasing the rate of growth.

v) Trade liberalization by developed countries could contribute substantially to sustained agricultural growth.

Developing countries (LDCs) typically have open economies in which agriculture is of substantial, if not dominant importance. For many, agricultural trade is an engine of growth. The conditions they face in the world commodity and financial markets largely determine the options open to them in formulating their own development strategy.

Research at IFPRI shows that substantial benefits would accrue to many developing countries through removal of tariff and non-tariff barriers by developed countries which artificially depress world prices and increase instability. It is suggested that the forthcoming GATT negotiations offer a new opportunity to develop a more rational international trade structure provided both developed and Third World countries are prepared to make some concessions, including removal of restrictive practices, taxes and exchange rates of trade policy-induced domestic price distortions in the latter. It has been shown that this could significantly improve rural incomes.

vi) Greater regional integration of food markets could increase security and sustainability.

Regional integration of food markets through trade can be a means of improving food security in LDCs by stabilizing domestic consumption; which, particularly in Africa, is closely linked to production instability.

Research in Southern Africa shows that regional stockpiling and other cooperative trade measures could:

- Save in storage and transportation costs.

- Compensate for fluctuations in production in individual countries.

- Substitute for national stockholding, and in some cases, for food imports.

- Help to promote comparative advantage in in production.

The prerequisite for achieving processing these benefits are some loss in national autonomy, the development of an effective intra-country institutional structure, and exchange-rate adjustments.

vii) Taxation and other fiscal measures can be instruments of land use policy.

The report suggests ways of improving the tax-base of agriculture in ways which do not act as a disincentive to production or other measures. Taxes or other measures (licenses, quotas, tariffs) may also be used to promote sustainable land use, although they may often be difficult to collect. They may be used as a stick or carrot. Generally, we favor measures to create incentives to partnership among land users or between them and the state, rather than punitive or rigid controls. However, price disincentives may be useful in discouraging some undesirable uses of land.

viii How can population growth be restrained without coercion?

While there is an inverse relationship between economic growth and population growth, the effects take time to have an impact. Many countries now seek more direct ways of reducing growth rates of population which threaten sustainability. Draconian measures may cause political instability. Investment in health services, housing clean water, and the provision of family planning guidance and facilities can hep to reduce the rate of population increase through voluntary restraints. Research is a continuing need. It is essential that donors support such efforts rather than looking the other way.