Sustainable Agriculture in Fragile Resource Zones

Technological Imperatives

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The prospects of sustainability for agriculture in the fragile areas are severely constrained by the specific features of their natural resource endowments. Sustainability, or rather survivability, in a situation of low pressure on resources was possible through traditional land extensive practices. In the changed circumstances with high pressure on fragile resources, the required high resource use intensity (for high productivity) with conservation is not possible through traditional measures. This requires application of modern science and technology blended with the rationale of indigenous practices. Various areas of focus for R and D are indicated to achieve this. Any progress in the suggested direction, however, will depend on the reorientation of agricultural research strategies to suit the specific requirements of these areas. This in turn is largely an institutional rather than a technological problem.

I
Introduction and Setting

THIS paper deals with agriculture in the fragile or marginal resource areas such as mountains and rainfed arid/semi-arid tropical plains. In these areas sustainability or rather unsustainability, is not a matter of probability, but an already felt reality. After a brief comment on the key issues involved in the mainstream debate on sustainability, the paper presents a few negative changes (i e, indicators of unsustainability) relating to the resource base and productivity in these regions. The negative changes are a consequence of current patterns of resource use that over-exploit the resources. The important resource characteristics (often ignored while using the resources) and their sustainability implications are also discussed. After commenting on the indigenous measures and conventional development interventions to handle the constraints of fragile resource-agriculture, the paper examines the need for complementing the two. Finally, the major areas requiring research focus and the technology for enhancing the sustainability of fragile resource-agriculture are discussed.

Sustainability Issues

The 'Sustainability' debate has created a great deal of concern in recent years. Besides the more publicised works such as 'Limits to Growth' by the Club of Rome in the seventies and 'Our Common Future' by the Brundtland Commission in the eighties, several significant contributions have been made to the subject and have been summarised by Pezzey [1989]. However, despite all this, 'sustainability' continues to be a much used metaphor, with only very little progress as far as making the concept operational is concerned [D' Riordan 1988]. The problems stem from the futuristic nature of the phenomenon and associated uncertainties; required specifications of contexts which can give operational meaning to the phenomenon; and the general neglect of the intra-generational aspects while focusing on the inter-generational issues as the core of the 'sustainability' debate. However, various definitions of sustainability, which largely describe the situations rather than define the term, do highlight some broadly common elements. The important ones, as synthesised by Pezzey [1989], are summarised below.

Conceptually speaking, the focus of 'sustainability' is on the issues of inter-generational equity. This implies equal (or greater) availability of options, in terms of human well-being or production prospects, to future generations as compared to the present one. Theoretical possibilities of such prospects, ensurable through accumulation of capital stock and technology for use by future generations, are constrained by the capabilities of the biophysical resource base. The latter cannot be stretched or manipulated indefinitely, without initiating processes of irreversible damage. This indicates the primacy of biophysical resources in sustainable development. This is more so in the case of agriculture, whose dependence on biophysical variables is more direct and crucial.

This could be further highlighted by the operational meaning of sustainability. The operational meaning of the term, as inferred from its definitions of descriptions, provided by ecologists, environmentalists, economists, and other scientists [Conway 1985; Myers 1986; Raeburn 1984; Tisdell 1987; Chambers 1987; Ruttan 1988; Lynam and Herdt 1988; 'Food-2000' 1987; and Markandya and Pearce 1988] which becomes clearer when related to specific situations, could be as follows: 'Sustainability' is the ability of a system (e g, the fragile resource-agriculture) to maintain a certain well-defined level of performance (output) over time, and, if required, to enhance the same, including through linkages with other systems, without damaging what Tisdell [1987] calls the essential ecological integrity of the system. Because of the time factor involved and the system's responsiveness to changing requirements, 'sustainability' is a dynamic (as against static) phenomenon. This distinguishes sustainability from mere subsistence and makes it compatible with development. By picking up the key threads from the mainstream debate on sustainability, this paper attempts to give operational content to some of the issues involved with reference to agriculture in the fragile or marginal resource areas.

Fragile Resource Regions

Before referring to the reasons for choice of the fragile areas, a word on fragility. A fragile resource is one which cannot tolerate the degree of disturbance implied by the intensity of use associated with specific usage. Thus, strictly speaking, fragility is a relative or context specific term. Every land resource is fragile, i e, vulnerable to irreversible damage, when subjected to a degree of use intensity higher than its use capability. Thus, the lands belonging to use-capability classes IV and above, though good for land-extensive uses, are fragile when assessed with reference to the use intensity implied by the intensive cropping associated with prime agricultural lands (i e, fertile, well drained lands with even topography and stable climatic conditions, conducive to crop farming).

There may be several other ways to look at the phenomenon of fragility. Besides describing fragility in terms of vulnerability to irreversible damage by higher use intensity [DESFIL 1988], one can describe it in terms of: low input absorption capacity of the resource; limited scope for resource manipulation; and required high level of biochemical subsidisation of the natural resource to achieve a level of output comparable to that from better land resources. The phenomenon can also be expressed in terms of input-output ratios, where the fragile lands have higher than average input-output ratios. Described this way, all areas with low potential for crop farming (mountain regions with steep slopes, deserts, rainfed arid and semi-arid tropical areas with low and unstable rainfall, and coastal areas prone to salinity and waterlogging, etc) will fall into the category of fragile resource areas (or fragile areas). Despite their apparent differences, for operational purposes fragility and associated attributes impart a degree of similarity, if not exact homogeneity, to these areas. This facilitates their consideration as a 'system' in the context of which sustainability issues can be understood and analysed.

In many parts of these areas, under the present patterns of resource use, the threshold limits to maintenance or enhancement of agricultural performance, even by using the inter-regional linkages, seem to have been reached. Further efforts to improve output levels imply over-exploitation of their biophysical resource base and initiation of the irreversible process of resource degradation [Glantz 1987; Nelson 1988; Grainger 1982; and Allan et al 1988]. These areas represent crisis zones, where the sustainability, usually conceived at conceptual or philosophical levels, has become an objective reality. The production prospects and output levels, on a per capita basis and in most cases a per production-unit basis, have declined. Thus, in these habitats, one can observe the emergence of the inter-generational inequities. Accordingly, compared to past generations the present one (unless supported externally) seems to have lower production prospects. The links between short-term intra-generational issues (poverty, inequity, etc) and long-term inter-generational issues (emphasised by the sustainability debate), are quite apparent in these areas. This in turn injects some relevance to the sustainability debate in the developing country context [Mellor 1988 and Jain 1988].

In light of the above, the fragile resource areas and their dominant activity, i e, agriculture—broadly defined to cover all land-based and allied activities, ranging from forestry to annual cropping—can offer a unique field-level laboratory for understanding the operational dimensions of sustainability. Though the fragile resource areas listed above are many, the following discussion relates to (i) the mountain areas; particularly lower and middle mountains where annual cropping is one of the land-based activities and (ii) the rainfed areas in the arid and semi-arid tropical regions (also referred to as dry tropical areas). Although the latter also includes some mountainous areas, our focus is mainly on the dry plain areas. Besides their magnitude and the availability of relevant data on them, my close acquaintance with the two regions, especially in South Asia, has dictated this choice. The mountain regions and dry tropical regions in the developing countries have several major differences. Hence, in the following discussion, when necessary, we will refer to the two areas separately. Wherever, they share common characteristics or descriptions we will treat them together and refer to them as fragile zones or marginal areas, etc. It may also be noted that, despite the domination of fragile land resources, these regions also have substantial pockets where fragility is not a problem.

Primacy of Biophysical Resource Base

'Sustainability' as mentioned earlier, is a dynamic phenomenon, as reflected through the system's responsiveness to changing requirements. In the more concrete context of agriculture in the fragile zones, this 'dynamism' translates into the capacities of production factors, mainly biophysical resources, to accommodate the increasing pressure of demand without damaging their long-term potentialities. The long-term productivity and health of the natural resource base is in turn affected by the pattern and intensity of its use. Thus, devoid of finer definitional differences, in essence, the sustainability/unsustainability is an outcome of match/mismatch between (i) basic characteristics of the natural resource components and (ii) patterns and methods of their utilisation. The latter can change (with the changing needs or perceptions of the community), but the former is normally difficult to change unless the whole resource base is transformed.

Given its inherent characteristics, the natural resource base of a system (e g, agriculture in the fragile areas) suits only some uses. Other uses (unless the resource base itself is modified) cannot be productively maintained without either a high degree of artificial support (e g, subsidies in chemical, biological, and physical forms) or damage to the inherent capacities of the resource base itself. In either case, inappropriate use of the resource base is a definite step towards long-term unsustainability. This problem is more specific to regions with fragile and marginal land resources such as the mountains and the dry tropical areas considered here. In such habitats the unsustainability situation

Table 1a: Negative Changes as Indicators of the Unsustainability of Agriculture (Mountain Areas)

Visibility of Change	Changes Related to[a]: Resource Base	Production Flows	Resource Use/Management Practices
Directly visible changes	Increased landslides and other forms of land degradation; abandoned terraces; per capita reduced availability and fragmentation of land; changed botanical composition of forest/pasture. Reduced water-flows for irrigation, domestic uses, and grinding mills.	Prolonged negative trend in yields of crop, livestock, etc, increased input need per unit production; increased time and distance involved in food, fodder, fuel gathering; reduced capacity and period of grinding/saw mills operated on water flow; lower per capita availability of agricultural products; etc.	Reduced extent of: fallowing, crop rotation, intercropping, diversified resource management practices; extension of plough to sub-marginal lands; replacement of social sanctions for resource use by legal measures: unbalanced and high intensity of input use, etc.
Changes concealed by responses to changes	Substitution of: cattle by sheep/goat; deep rooted crops by shallow rooted ones; shift to non-local inputs Substitution of water flow by fossil fuel for grinding mills; manure chemical fertilisers[b]	Increased seasonal migration; introduction of externally supported public distribution systems (food, inputs)[b] intensive cash cropping on limited areas.[b]	Shifts in cropping pattern and composition of livestock; reduced diversity, increased specialisation in monocropping; promotion of policies/programmes with successful record outside, without evaluation.[b]
Development initiatives, etc, potentially negative changes[c]	New systems without linkages to other diversified activities; generating excessive dependence on outside resource (fertiliser/pesticide based technologies) ignoring traditional adaptation experiences (new irrigation structure).	Agricultural measures directed to short term quick results; primarily product—(as against resource) centred approaches to agricultural development, etc.	Indifference of programme and policies to mountain specificities, focus on short term gains, high centralisation, excessive, crucial dependence on external advice ignoring wisdom.

Notes: a Most of the changes are interrelated and they could fit into more than one block.
b Since a number of changes could be for reasons other than unsustainability, a fuller understanding of the underlying circumstances of a change will be necessary.
c Changes under this category differ from the ones under the above two categories, in the sense that they are yet to take place, and their potential emergence could be understood by examining the involved resource use practices in relation to specific mountain characteristics.

emerges more quickly and in a more pronounced manner. In the natural state in these areas, the range of options ensuring a proper match between resource characteristics and resource use is very narrow. However, due to human ingenuity over the generations, the range of options has been widened. Features of traditional farming systems in these regions corroborate this [Whiteman 1988; Moock 1986; ICRISAT 1980; Altieri 1987; and Jodha 1988]. However, these options, having evolved in the context of low demand on fragile resources, are becoming increasingly unfeasible or ineffective in the context of the new pressures generated by population growth, market forces, and public interventions [Liddle 1975; Rieger 1981; and Jodha 1986a, and 1989c]. The consequent measures, such as the extension of cultivation to more fragile and sub-marginal locations; the push towards monoculture induced by promotion of selected HYV crops; or the steps leading to overstocking of grazing lands and deforestation to compensate for the falling incomes, adopted to meet the situation, often fail to match well with the constraints and potentialities of the fragile resources [Liddle 1975; Sanwal 1989; and Jodha 1986b, 1988]. A not unexpected result, is the emergence of indicators of unsustainability. In such situations the reestablishment of a 'match' between resource characteristics and their use-patterns, is an important step in enhancing the sustainability of fragile resources and the activities, including agriculture based on them.

At the conceptual level, the above reasoning implies a change in the perspectives on the sustainability question. Accordingly, for identifying and operationalising the components of sustainability for a given system, one needs to examine the unsustainability phenomenon first and then proceed backwards to understand the factors and processes contributing to it. This can help in identifying practical mesures to reverse the process leading to unsustainability. A practical step towards implementing the above approach is to prepare an inventory of the indicators of unsustainability in a system and then look into the 'why and how' behind them. This approach has some merits. It can help in improving the understanding of operational aspects of the issues involved in the sustainability debate. This also helps to relate more easily the involved issues to the real world situations in which the causes and consequences of unsustainability are felt. It can also help to identify concrete steps to modify the current approaches towards development and resource management. Such steps may relate to macro and micro-level policies and programmes as well as to farm level decisions and actions. The above approach forms the basis of the current work at ICIMOD, directed towards identifying the elements of sustainability to incorporate into strategies for agricultural development in the Hindu Kush-Himalayan (HKH) Region [Jodha 1989a]. Using the above framework, we will discuss first the indicators of unsustainability characterising the mountains and the dry tropical regions. This will be followed by a description of resource characteristics, the disregard of which, at different levels, is primarily responsible for the emerging indicators of unsustainability. The sustainability implications of the resource characteristics are indicated. This will be

TABLE 1b: NEGATIVE CHANGES AS INDICATORS OF THE UNSUSTAINABILITY OF AGRICULTURE (DRY TROPICAL AREAS)

Visibility of Change	Changes Related to[a]		
	Resource Base	Production Flows	Resource Use/Management Practices
Directly visible changes	Various forms of resource degradation: Emergence of salinity coverage of fertile soil by shifting sands, vanishing top soils due to water/wind erosion; deepening of water tables, ground water salinisation; emerging plantless-ness, reduced perennials, increased inferior annuals and thorny bushes; reduced per capita availability of productive resources.	Reduced total and per capita biomass availability; reduced average productivity of different crops, increased cropping on sub-marginal lands; reduced enterprise product recycling; higher dependence on inferior options, (e g, harvesting/lopping premature trees), rising severity of successive drought-impacts; increased dependence on public relief, increased migration.	Changes in landuse pattern: cropping on sub-marginal lands; decline of common property resources; reduced diversity of agriculture (e g, number of crops/enterprise and their inter-linkages); reduced feasibility and effectiveness of traditional adaptation strategies (e g, rotations, inter-cropping, biomass strategies).
Changes concealed by responses to (negative) changes	Substitution of cattle, camels, by small ruminants; increased emphasis on mechanisation of cultivation and water lifting; reduced idling of land; large scale 'reclamation' (!) of wastelands; shift from local to external inputs (e g, from manure to chemical fertilisers, wooden tyre to rubber tyres for bullock carts).[b]	Higher coverage by public distribution system (food, inputs) and other anti-poverty programmes;[b] reduced reliance on self-provisioning system and greater dependence on external market sources; changes in landuse pattern favouring grain production.	Discarding of minor crops, shift towards monocropping with standardisation inputs/practices; increased landuse intensity; shift from two-oxen to one—ox plough; tractorisation;[b] practices; replacement of self-help systems by public support systems.
Development initiatives, etc,—potentially negative changes[c]	R and D focus on: crop rather than resource; technique rather than user—perspective (e g, method/species/inputs rather than group action for watershed/range development); resource upgrading ignoring its limitations (e g, irrigation in impeded drainage areas); inducing high use intensity of erodable soils, and other resource extractive measures (e g, tractorisation).	Highly subsidised, narrowly focused production programmes: focus on crops ignoring other land based activities; grain yield ignoring biomass; monocropping ignoring diversification; relief operations focused on people and livestock ignoring resource base, thus promoting high pressure on poor resource base.	Sectoral focus of R and D and other support systems ignoring flexibility and diversification needs; privatisation of common property resources; extension of generalised external approaches to specific areas: disregard of folk knowledge in formal interventions; replacing local informal arrangements by rigid legal/administrative measures.

Notes: a Most of the changes are interrelated and they could fit into more than one block.
b Since a number of changes could be for reasons other than unsustainability, a fuller understanding of the underlying circumstances of a change will be necessary.
c Changes under this category differ from the ones under the above two categories, in the sense that they are yet to take place, and their potential emergence could be understood by examining the involved resource use practices in relation to specific area-resource characteristics.

followed by a brief discussion of the extent to which these implications, have influenced production and resource management practices under the traditional farming systems, and the conventional development approaches to agriculture in the fragile zones. The sustainability-promoting features of the two are highlighted to indicate the possible scope for blending them for enhanced sustainability of agriculture. Their practical implications are presented as the potential focus areas for research and technology development (R and D) for fragile resource-agriculture. The discussion on equally important institutional and demographic factors for sustainable agriculture falls outside the scope of this paper.

II

Fragile Regions: Dominant Scenario

The dominant scenario characterising most of the fragile regions in developing countries, particularly those with high population pressure, is the widening gap between development efforts (indicated by investment and public interventions) and the corresponding achievements in terms of measurable economic gains (especially on a per capita basis) and qualitative changes, such as the health and production potential of the natural resource base, environmental consequences, etc.

During the brief period of 40 to 50 years, several alarming trends have emerged in different parts of the mountains and the dry tropical regions. There are, in these regions, clearly visible, persistent negative changes, relating to crop yields, availability of other agricultural products, the economic well-being of the people, and the overall condition of environment and natural resources [Rieger 1981; Jodha 1988; Glantz 1987; and Blaikie and Brookfield 1987]. For instance, in mountain areas at present, in comparison to the situation 50 years ago, the extent and severity of landslides is higher; water flow in traditional community irrigation systems (*kools*) is lower; yields of major crops in the mountains (except in highly patronised pockets) are lower; diversity of mountain agriculture is reduced; the inter-seasonal hunger gap (food deficit period) is longer; time spent by villagers for collection of fodder and fuel from neighbouring uncultivated areas or common property lands is longer; the botanical composition of species in forests and pastures has undergone negative changes; and finally, the extent of poverty, unemployment and out-migration of the hill people has increased. Ives and Messerli [1989] refer to some of the persistent negative changes referred to above in the Himalayan context. Work on an inventory of such measurable, verifiable or objectively assessable changes in the selected hill areas of Nepal, India, Pakistan, and China is in progress [Jodha 1989a].

In the case of dry tropical areas, various forms of resource degradation including increased salinity (of both soil and ground water), deepening of water tables, disappearance of plants from pastures and community forests, and increase of areas under shifting sand are quite visible. Similarly, during recent decades decline in overall biomass availability, substitution of cattle (and camels in arid areas) by sheep and goats, and the extension of cropping to submarginal areas to meet production deficits have been observed. Reduced productivity and reduced resilience of the traditional farming systems have led to increased dependence on public relief and increased seasonal migration to other areas. Various facets of the decline have been recorded by different studies [Jodha 1986a, 1988; Dixon et al 1989; Warren and Agnew 1988; and Glantz 1987]. However. the situation in the limited areas transformed through dependable irrigation systems is quite different.

Indicators of Unsustainability

The above negative changes, treated as indicators of unsustainability, may relate to:
(a) resource base (e g, land degradation),
(b) production flows (e g, persistent decline in crop yields), and
(c) resource management/usage systems (e g, increased unfeasibility of annual-perennial based intercropping or specific crop rotations, etc).

More importantly, for operational and analytical purposes, the indicators can be grouped under the following three categories on the basis of their actual or potential visibility. Tables la and lb (Annex) summarise some of them for the mountain areas and the dry tropical areas respectively.

(i) *Directly Visible Negative Changes*. In the case of mountain areas, these can include increased landslides or mudslides; drying of traditional irrigation channels (*kools*); increased idle periods of grinding mills or saw mills operated through natural water flows; prolonged fall in the yields of crops in mountains; reduced diversity of mountain agriculture; abandonment of traditionally productive hill terraces; and increased extent of seasonal out-migration of hill people.

In the case of dry tropical areas, such changes are reflected in various forms of resource degradation and desertification and their impacts. Some of these include accentuated soil erosion; increased salinity of soil and ground water; increasing severity of drought-induced scarcities; reduced feasibility and efficacy of traditional adaptations against weather risks; reduced overall biomass availability; and reduced carrying capacity of pastures.

(ii) *Negative Changes Made Invisible*: People's adjustments to negative changes often tend to hide the latter. In both the mountain areas and dry tropical areas such changes can include: substitution of shallow-rooted crops for deep-rooted crops, following the erosion of top soil; substitution of cattle for small ruminants due to permanent degradation or reduced carrying capacity of grazing lands; introduction of public food distribution systems due to the increasing inter-seasonal hunger gaps (local food production deficits); small farmers leasing out their lands to concentrate on wage earning; and shift towards increased external inputs in cropping due to the decline of locally renewable resources.

(iii) *Development Initiatives with Potentially Negative Consequences*: A number of measures are adopted for meeting present or perceived future shortages of products at current or increased levels of demand. Some of the measures (changes), while enhancing productivity of agriculture in the short run, might jeopardise the ability of the system to meet the increasing demands in the long run. Chances of such happenings are positively linked with the interventions' insensitivity to specific conditions of the fragile resource areas [Franke and Chasin 1980; Altieri 1987; and Jodha 1986b].

In the context of mountain agriculture, the above can be illustrated by any farm technology that increases mountain agriculture's crucial dependence on external inputs (e g, fertiliser) as against the locally renewable input resource, or adds to mass production of high weight, low value products with a largely external market ignoring the inaccessibility and related problems. Similarly, any measure that disregards the 'fragility of mountain slopes and ignores linkages among diverse activities at different elevations in the same valley (e g, farming-forestry linkages) and promotes monocropping may not prove sustainable. In the dry tropical areas, any intervention that disregards the totality of the farming system (covering crop, livestock, and their support mechanisms); over emphasises grain yield at the cost of total biomass; focuses on high cost inputs for low value coarse grains; and attempts to upgrade resources (e g, by irrigation) ignoring soil characteristics and the impeded drainage situation, etc, can not ensure sustainability of agriculture.

Under categories (ii) and (iii) above, there may be several changes, which might bring positive results in the long run and enhance the sustainability of agriculture in the fragile areas. To separate them from negatively oriented changes, one needs a fairly detailed analysis of the involved components. This involves examination of the implications of interventions in terms of their compatibility with the relevant characteristics and conditions of the fragile areas. The important resource characteristics, described also as resource specificities [Jodha 1989a], and to be discussed are: inaccessibility, fragility, marginality, diversity, niche, and the adaptation mechanisms of people in these habitats. The relative importance of these characteristics may vary between the mountains and the dry tropics. However, to a great extent most of them are shared by the two. These can be used for screening the relevant interventions and sustainability implications for fragile resource-agriculture. The utility of such an effort will depend on (i) identification of factors and processes contributing to the persistent negative trends and (ii) identification of measures ot handle such factors and processes. The rapid growth of population pressure, increased role of market forces, and the side effects of public interventions in the recent decades are often identified as basic factors causing and accentuating the negative trends mentioned earlier [ERL 1988; Repetto 1986; Banskota 1989; Jodha 1986b; and Grainger 1982].

However, without questioning the impacts of the above factors, two points need emphasis. Firstly, in today's context neither market nor public intervention (and even population growth in the near future) can be wished away. Secondly, it is not so much the presence of these factors but rather their interaction-patterns with the fragile resources and environments that matters [Grainger 1982; Jodha 1986a; and Tolba 1987]. Understanding of the latter calls for identification of relevant characteristics and conditions of these areas and examination of how they are affected by the factors and pressures inducing changes in the pattern and intensity of resource use.

III
Resource Characteristics and Sustainability Implications

There are a number of important conditions or characteristics of the fragile resource areas which, for operational purposes, separate them from the prime agricultural areas. The six important characteristics are considered here. The first four, namely, inaccessibility (more relevant in the mountains than in the dry tropical plains), fragility, marginality, and diversity or heterogeneity, may be called first order characteristics. Natural suitability or 'niche' (including man-made ones) for some activities/products, in which these areas may have comparative advantages over the other areas, and 'human adaptation mechanisms' are the two second order characteristics considered here. The latter are different from the former, in the sense that they partly represent human responses or adaptations to the first order characteristics. However, they are specific to these areas nevertheless [Jodha 1989a].

Before describing the major resource characteristics, it should be noted that the latter are not only interrelated in several ways, but, within the fragile areas, they show considerable variability. For instance, all locations in the mountain areas are not equally inaccessible. Similarly, all areas in the mountains or the dry tropics are not equally fragile or marginal. Neither do human adaptation mechanisms have uniform patterns in all mountain habitats or all dry tropical areas. With full recognition of such realities, we may briefly introduce the aforementioned characteristics.

INACCESSIBILITY

Due to slope, altitude, overall terrain conditions, and periodical seasonal hazards (e g, landslides, snow storms, etc) inaccessibility is the most known feature of mountain areas [Price 1981 and Hewitt 1988]. In the dry tropical areas, inaccessibility is not of the same order as in the mountains, but it is important when compared with the high productivity, well watered agricultural zones [Jodha 1986a]. The concrete manifestations of inaccessibility are isolation, distance, poor communications, and limited mobility with all their sociocultural and economic implications. The mountains and the dry tropics share these manifestations and implications more significantly than the physical dimensions of inaccessibility. The sustainability implications of such relatively 'closed' systems, created by inaccessibility will be discussed later.

Fragility

Fragility is the dominant characteristic on the basis of which the mountain areas and the dry tropical areas are chosen for the present discussion. Fragility is an attribute of the resources that emanate from the combined operation of slope/altitude or undulating topography as well as geologic, edaphic, and biotic factors. Notwithstanding the differences in the relative roles of the specific factors in the mountains and the dry tropics, these factors in their respective ways limit the capacities of land resources to withstand even a small degree of disturbance [DESFIL 1988]. Vulnerability to irreversible damages due to overuse or rapid changes, extends to physical land surface, vegetative resources, and even the delicate economic life-support systems of the dependent communities. Consequently, when resources and environment start deteriorating due to disturbance, they do so rapidly. In most cases, the damage is irreversible or reversible only over a long period [Eckholm 1975; Hewitt 1988; Warren and Agnew 1988 and Grainger 1982]. The sustainability implica-

TABLE 2: SUSTAINABILITY IMPLICATIONS OF MOUNTAIN SPECIFICITIES

Mountain Specificities (and objective circumstances)	Sustainability Implications in Terms of: Inherent Production Potential and Modification Possibilities through:					Abilities to Link with Wider System	
	Resource Use Intensity	Input Absorption Capacity	Infra-structural Logistics	Gains of Scale	Resilience to Shocks	Surplus Generation and Exchange	Repli-cability of External Experience
Inaccessibility: (Remoteness, distance, closeness, restricted external linkages, etc)	(−)[a]	(−)	(−)	(−)	(−)	(−)	
Fragility: (Vulnerability to irreversible damage, low carrying capacity, limited production options, high overhead cost of use, etc)	(−)	(−)	(−)		(−)	(−)	(−)
Marginality: (Cut off from mainstream, limited production option, high dependency, etc)		(−)	(−)	(−)	(−)	(−)	(−)
Diversity: (Complex of constraints and opportunities, interdependence of production bases and products/activities, etc)	(+)[a]	(+)	(+)	(−)	(+)	(+)	(−)
'Niche' (Small and numerous specific activities with comp. advantage; use of some beyond local capabilities, etc)	(+)	(+)	(+)	(−)	(+)	(+)	(−)
Adaptation Mechanisms: (Folk agronomy, ethno-engineering, collective security, diversification, self-provisioning, etc)	(+)	(+)	(+)	(−)	(+)		(+)

Note: a (−) indicates extremely limited possibilities, while (+) indicates greater scope for sustainability through production performance and linkages with wider systems (e g, upland-lowland interactions).

RALLIS INDIA LIMITED

It is hereby notified for the information of the public that RALLIS INDIA LIMITED proposes to make an application to the Central Government in the Department of Company Affairs, New Delhi, under Sub-Section (2) of Section 22 of the Monopolies and Restrictive Trade Practices Act, 1969, for establishment of a new undertaking.
Brief particulars of the proposal are as under:

1. Name and address of the applicant	:	Rallis India Limited Ralli House, 21, D.S. Marg, Bombay 400 001.
2. Capital structure of the applicant organisation	:	Capital structure as on 31st March, 1990:

	(Rs. lacs)
AUTHORISED:	
1,00,00,000 Ordinary Shares of Rs. 10/- each	1000.00
ISSUED AND SUBSCRIBED:	
95,30,697 Ordinary Shares of Rs. 10/- each	953.07
Add: Amount paid up on forfeited shares	0.02
	953.09

3. Management structure of the applicant organisation indicating the names of the Directors including Managing/ Wholetime Directors and Manager if any.

Mr. D.S. Seth	—Chairman	Mr. V.J. Sheth	—Director
Mr. D. Sabikhi	—Executive Vice-Chairman	Mr. H.J. Silverston	—Director
Mr. Y.N. Mafatlal	—Director	Prof. R.J. Taraporevala	—Director
Dr. F.A. Mehta	—Director	Dr. Ram S. Tarneja	—Director
Mr. V.N. Nadkarni	—Director	Mr. R.D. Thomas	—Director
Mr. S. Parthasarthy	—Diector	Mr. V. Rai	—Managing Director
Mr. D.R. Peters	—Director	Mr. B.K. Laskari	—Executive Director & Secretary
Mr. J.K. Setna	—Director		

4. Indicate whether the proposal relates to the establishment of a New Undertaking or a New Unit/Division.	:	The proposal relates to a manufacturing facility being set up at Ankleshwar, Bharuch, Gujarat where the Company has an established infrastructure
5. Location of the New Undertaking/Unit/ Division	:	The new undertaking will be situated at Plot No. 3301, GIDC Estate, Ankleshwar, Gujarat - 393 002
6. Capital structure of the Unit/Division/ Undertaking	:	Same as in (2) above

7. In case the proposal relates to the production, storage, supply, distribution or marketing or control of any goods/articles indicate:

i) Names of goods/articles	:	Manufacture of Triazole (Fungicide) (Hexaconozole)
ii) Proposed Licensed Capacity	:	100 Tonnes per annum
iii) Estimated Annual Turnover	:	Rs. 1000 lacs
8. In case the proposal relates to the provisions of any services, state the volume of activity in terms of usual measures such as value, income, turnover.	:	Not applicable
9. Cost of the project	:	Rs. 145.00 lacs

			(Rs. in lacs)
10. Scheme of finance indicating the amounts to be raised from each source	:	Internal resources	145.00
			145.00

Any person interested in the matter may make a representation in quadruplicate to the Secretary, Department of Company Affairs, Government of India, Shastri Bhavan, New Delhi, within 14 days from the date of publication of this notice, intimating his views on the proposal and indicating the nature of his interest thereon.

RALLIS INDIA LIMITED

B.K. LASKARI
EXECUTIVE DIRECTOR & SECRETARY

Dated this 22nd day of March 1991.

tions of this characteristic, to be discussed later, are not difficult to perceive.

Marginality

'Marginality' is another characteristic of these areas which is directly related to fragility. A 'marginal' entity (in any context) is the one which counts the least with reference to the 'mainstream' situation. This may apply to physical and biological resources or conditions as well as to people and their sustenance systems. The basic factors, contributing to such a status of any area or a community, are remoteness and physical isolation, fragile and low-productivity resources, and several man-made handicaps which prevent one's participation in the 'mainstream' of activities [Chambers 1987 and Lipton 1983]. The mountains and dry tropical plains being marginal areas, in most cases, when compared with the prime agricultural regions, share the above attributes of marginal entities and face the consequences of such a status in different ways [Bjonness 1983 and Jodha 1988]. Marginality shares with fragility a number of sustainability implications, as will be discussed later.

Diversity or Heterogeneity

The fragile areas chosen for the present discussion are internally not homogeneous even in terms of fragility or marginality. As mentioned earlier, all the characteristics listed here show considerable internal diversity. In the mountain areas, one finds immense variations among and within eco-zones, even over short distances. This extreme degree of heterogeneity is a function of interactions of different factors ranging from elevation and altitude to geologic and edaphic conditions [Troll 1988]. In the case of the arid and semi-arid tropical plains, the degree of diversity (though less compared to the mountains) is primarily because of topography, soils, and precipitation differences [Dixon et al 1989]. Water—a homogenising factor—being limited, the diversity of other land resources persists. The biological adaptations [Dahlberg 1987] and socio-economic responses to the above diversities [Price 1981; Jochim 1981; and Nogaard 1984], also acquire a measure of heterogeneity of their own. Diversity serves as a source of a complex mixture of constraints and opportunities characterising these areas. As a positive attribute supporting interlinked activity patterns, diversity can help enhance the sustainability of agriculture in these areas.

'Niche' or Comparative Advantage

Owing to their specific environmental and resource-related features, both the mountains and the dry tropics provide a 'niche' for specific activities or products [Jodha 1988 and 1989a]. At the operational level, these areas may have comparative advantages over other areas in these activities. In the case of mountain areas the examples may include: specific valleys serving as habitats for special medicinal plants; mountains acting as a source of important high value products (e g, fruits, flowers, etc); and mountains serving as the best known sources for hydropower production. The dry tropical plains, though less productive than the high rainfall mountain areas and having some similarities with other plain areas, may also have comparative advantages for land-extensive activities (e g, pasture-based animal husbandry), highly moisture (or humidity)—sensitive cultivars, such as some coarse grains, etc. In practice, however, niche or comparative advantage may remain dormant unless circumstances are created to harness them. The local communities make use of these 'niches' through their diversified activities. Proper harnessing of niches can support sustainability, while their reckless exploitation can result in the elimination of niches.

Human Adaptation Mechanisms

Mountains and dry tropical plains, through their heterogeneities and diversities even at micro-level, offer a complex of constraints and opportunities. The local communities in these areas, through trial and error over the generations, have evolved their own adaptation mechanisms to handle them [Guillet 1983; Jochim 1981; Moock 1986; Whiteman 1988; and Jodha 1988 and 1989c]. Accordingly, either the resource characteristics are modified (e g, through terracing, trenching, ridging, and irrigation) to suit their needs; or activities are designed to adjust the requirements to resource conditions (e g, by zone specific combinations of livestock, crops, and horticulture). Adaptation mechanisms are reflected through formal and informal arrangements for management of resources; diversified and interlinked activities to harness micro-niches in specific eco-zones; and effective use of links with other habitats. The adaptation mechanisms helped in the sustainable use of fragile resources in the past. However, with the changes already indicated (e g, relating to population, market, and public interventions), a number of adaptation devices are losing their feasibility and efficacy. It may be noted that understanding their rationale can help in designing options for sustainable agriculture in the fragile resource areas, as will be elaborated upon later.

Sustainability Implications: The sustainability implications of the above characteristics of fragile areas can be understood in terms of the degree of convergence between: (i) objective circumstances (e g, operationally relevant constraints and potentialities) created by them and (ii) conditions associated with the process of sustainable development (e g, ability of a system for sustained performance without damaging its essential ecological integrity). To elaborate on this, we need to refer back to the operational meaning of sustainability mentioned earlier. Accordingly, sustainability (i e, sustained or increased level of production performance) is conditioned by the capacities of the biophysical resource base to withstand high use intensity; to absorb high quantities of complementary inputs; to tolerate periodical shocks/disturbances without facing permanent damage; to ensure gains associated with the scale of operation and infrastructural logistics; and to gain from linkages/exchanges with other (wider) systems. Juxtaposition of the above requirements (or preconditions of sustainability) and the already discussed characteristics of fragile resource areas can greatly clarify the sustainability problems of fragile resource-agriculture. This is attempted through Table 2. Despite some specific differences relating to inaccessibility and heterogeneity between the mountains and the dry tropical plains, the issues summarised under Table 2 broadly apply to both.

According to Table 2, due to features such as fragility, marginality, and inaccessibility, agriculture in the fragile areas has a very narrow production base and limited production as well as surplus generation possibilities. Because of these very factors, scope for resource manipulations through higher input use and higher use intensity is quite limited. Vulnerability of land resources to rapid degradation (as reflected by soil erosion, landslides, etc), even through minor disturbances, is also linked to fragility.

However, owing to the heterogeneity of habitats, agriculture in these areas is also endowed with a complex of varied opportunities for land-based activities. Local communities skillfully harness them. But being too diverse and narrow, and being constrained by marginality and inaccessibility, they cannot impart the benefits of large-scale operations. Benefits from the experiences of other ecological zones are also less likely, because the heterogeneities restrict the replication of external experiences to a substantial degree.

Niches or specific situations/products, with potential comparative advantages to these habitats over other areas, are also a product of heterogeneity characterising the fragile regions. Some of them are quite narrow and often harnessed to support petty trading despite poor market linkages and inaccessibility problems. Special horticultural products; such as flowers, medicinal plants, and animal products; may serve as examples. As discussed elsewhere [Jodha 1989a], mountains are also endowed with niches which are too huge and complex (e g, potential for large scale-irrigation and hydropower production), and the harnessing of them is often beyond the capacity of individual mountain communities.

IV
Search for Sustainability

Table 2 presents a broad view of the complex of constraints and potentialities created by the natural resource base of the fragile resource areas. It can also serve as a framework within which the search for sustainable agriculture can be directed. The major areas that need attention for the above purpose can be presented in the form of some focused questions.

(i) In view of the fragility, marginality, and, to some extent, inaccessibility problems, how can the use intensity of land and its (physical and economic) input absorption capacity be enhanced without negative side effects in terms of resource degradation?

(ii) What are the options for developing a complex of diversified activities with clear focus on: (a) high productivity despite low land use intensity and low input regimes (especially external inputs); (b) fuller use of resource diversities and niches (i e, the options with comparative advantages), without over exploitation and degradation of resources?

(iii) How to strengthen the resilience of farming systems to cope with the periodical shocks/stresses and the rapid growth of pressure on fragile resources?

(iv) What should be the potential forms and patterns of linkages of fragile resource agriculture with other systems (i e, agriculture and the general economy of other zones), in order to facilitate accomplishment of potential options under the above (i-iii) questions?

Past Strategies

The aforementioned issues, even though not formulated in the above manner, have, in the past, been addressed in various ways. Rural communities have evolved and inherited their adaptation strategies to handle the above problems. In recent decades, through development interventions, the same problems have been focused more formally. Table 3 summarises the relevant components of the two which are directed to resource management and productivity growth in agriculture. Table 3 reveals both the strengths and weaknesses of the two approaches. A synthesis of the strengths of the two, may help in identifying the directions and possible first order options to enhance the sustainability of fragile resource-agriculture.

By way of a comment on Table 3 the following may be stated. Traditional measures and practices have been evolved by people through informal experimentation over the generations [Chambers et al 1989 and Altieri 1987]. Hence, they are better adapted to limitations and potentialities of the fragile resources. Broadly speaking, they are location specific and small in scale; diversified and interlinked in their structure and operations; often land extensive and locally renewable resource centred; mainly supported by folk knowledge and informal social sanctions; and generally have lower input use and lower productivity. For the above reasons, they are conducive to sustainable resource use under low pressure of demand in relatively isolated or inaccessible situations. But they are becoming increasingly unfeasible and ineffective in the context of rising pressure on fragile land resources.

The measures promoted through conventional public interventions in the fragile resource zones, on the other hand, generally represent the extension of land intensive production system characteristics of relatively better agricultural areas [Altieri 1987 and Jodha 1986b]. So far they are not well adapted to the fragile resources. The public interventions, on their current scale and level of standardisation, are a recent phenomenon in these areas. Being in the early stage of evolution compared to traditional measures, probably they can be modified to suit the situation in fragile zones. Their major strengths are the significant input of modern science and technology; strong (public exchequer based) resource support; and conscious decisions and efforts to relax the development constraints of the fragile resource areas. They have significant potential for strengthening physical and market linkages among fragile zones and other regions. It should, however, be noted that past efforts based on these positive attributes have not strengthened the prospects of sustainable development in the areas under discussion. On the contrary, several indicators of unsustainability have emerged side by side with development efforts. The primary reason for this has been the general insensitivity of public interventions to specific conditions of the fragile zones. To impart this sensitivity, an effective approach would be to redesign the interventions by blending the rationale of traditional measures with the formal technological interventions [Chambers et al 1989].

Viewed differently, the whole issue of sustainability of agriculture in the fragile areas, can be reduced to a problem of increased use intensity of land resources (for higher productivity) without permanently damaging them. The indigenous systems, though oriented to resource use with conservation, do not possess high productivity technological components to ensure high use intensity and resource conservation simultaneously. The new science and technology-based interventions have capacity to raise use intensity and productivity of land but they are generally indifferent to conservation considerations. The above facts form the basic ground for blending the positive features of

TABLE 3: MEASURES AGAINST CONSTRAINTS TO SUSTAINABLE AGRICULTURE IN FRAGILE RESOURCE ZONES (INDIGENOUS SYSTEMS/DEVELOPMENT INTERVENTIONS)

Measures Adopted Under: Traditional Farming Systems	Conventional Development Interventions
(A) Enhancement of Use Intensity/Input Absorption Capacity of Land	
Measures	
Resource amendments by ethno-engineering measures: terracing/trenching/ridging, moisture conservation/drainage management/shelterbelts/agro-forestry, etc	Selective resource upgrading through irrigation/other infrastructure, biophysical changes (e g, new introduction; R and D activity/pilot projects for range lands, watersheds, etc).
Attributes Conducive to Sustainability	
Local resource centred, community oriented and supported, small scale, diverse, adapted to local situation; linked to other activities.	Science and technology input, strong logistic/resource support, advantage of scale.
Limitations	
Reduced feasibility with rising pressure on land and weakening of local level collective arrangements lack new high productivity components.	Side effects of massive interference with fragile resources (water logging, salinity, landslides); inequities between transformed (e g, irrigated) and leftover areas; insensitivity of R and D based initiatives to local resource diversity and user perspective.
(B) Usage and Management of Low Use-Capability Lands	
Measures	
Folk agronomy involving activities with low land intensity and low (local and affordable) input regimes; integration of low intensity-high intensity land uses (based on annual-perennial plants, crop-fallow rotations, indigenous agro-forestry, common property resources; social sanctions, resource use regulation; migration/transhumance	Sectorally separated production programmes; high intensity uses through new technology inputs/incentives/subsidies; focused conservation oriented initiatives (forests/pastures/watersheds) in projects largely in mode.
Attributes Conducive to Sustainability	
Diversified, interlinked activities with different levels of intensity, community participation, control on local demand.	New technological input, resource support and legal sanctions.
Limitations	
Reduced feasibility and effectiveness due to population growth, decline of collective arrangements, and side effects of dominated; technological and institutional interventions.	General indifference to resource limitations, user perspective; 'Technique' and 'project mode" dominated.

(Contd)

TABLE 3 *(Contd)*

Measures Adopted Under: Traditional Farming Systems	Conventional Development Interventions
(C) Options to Harness Diversity and Niches	
Measures	
Folk agronomy—diversified cropping, focus on multiple—use species; complementarity of cropping—livestock—forestry/horticulture; emphasis on biomass in choice of land use and cropping patterns; complementarity of spatially/temporally differentiated land-based activities; stability oriented, location specific choices, harnessing niches for tradable surplus.	Sectorally segregated programmes and their support systems (R and D, input supplies, crop marketing); focus on selected species and selected attributes (e g, monoculture, high grain: stalk ratio); extension of generalised development experience of other habitats with high subsidy.
Attributes Conducive to Sustainability	
Diversity, linkages as dictated by resource characteristics; locally renewable resource focused.	Initiatives with strong technological and logistic components, high potential for generating new options.
Limitations	
Low productivity, land extensive measures incompatible with high man land ratio, and changed institutional environment.	Indifferent to the totality of farming system and diverse resource potentialities; high subsidisation.
(D) Resilience of the System and Mechanisms to Handle High Pressure of Demand	
Measures	
Diversification and linkages of landbased activities; flexibility in scale, operations, input use; locally renewable resource focus, recycling of inputs/products, self provisioning; crisis period collective sharing arrangements, common property resources, social regulations for rationed use and protection of fragile resources; release of periodic/seasonal pressure by migration, transhumance, remittance economy	Public relief and support during crisis/scarcities; public interventions replacing traditional self-help strategies and informal regulatory measures; highly individual (not community)—focused interventions (e g, privatisation of common property resources, crisis period cushion promoted by increased private-resource productivity by HYVs, etc; occasional linking of relief measure with productivity measures.
Attributes Conducive to Sustainability	
Range of options to match specific constraints of the habitats; emphasis on community centred and regulated activities; rationing of demand on fragile resource.	Resource transfer from better off areas to scarcity prone areas; possibility of linking relief initiatives with resource conservation/production programmes.
Limitations	
Infeasibility and reduced efficacy of collective self-help measures and folk agronomic devices, due to changed demographic, institutional, and technological environment.	Dependency for sustenance on external resources; encouragement for perpetual growth of pressure on fragile resources; indifference to local self-help initiative.
(E) Linkages with Other Systems (including Wider Market Systems)	
Measures	
General state of relative inaccessibility (particularly for mountains) and isolation from main stream market; limited linkages agriculture/through tradable surplus from harnessing niches; crisis period external dependence through transhumance, migration, pockets, and remittance economy.	Improved physical and market linkages; integration of fragile resource economy with other systems; focus on special area development programmes, transformation of limited demonstration effects.
Attributes Conducive to Sustainability	
A few positive side effects of isolation, local demand centred, socially controlled extraction of fragile resources, better links between the resource users and the resources.	Improved opportunities for relaxing internal constraints through technology, resource transfer, interactions with other systems; inducement for fuller use of niches through external demand; closer integration with mainstream.
Limitations	
Persistent neglect and marginal status of fragile resource areas; slow pace of transformation of agriculture; unfavourable terms of exchange for marginal areas and products.	Unless guarded against; high chances of extending irrelevant external experiences (including technologies); external demand induced heavy extraction of niches; unfavourable terms of exchange; distortion in local demand patterns and resource use.

the two [Dregne 1983 and Jodha 1986b].

To facilitate such blending, some areas or issues may be suggested, that can be focused by research and technology development (R and D) efforts. Table 4 summarises them, along with their potential impact areas, to enhance the sustainability of agriculture. Concentration on these subject areas would require substantial reorientation of R and D strategies in the fragile zones. This would imply making research and technology measures more resource-centred, system-oriented, and conducive to harnessing the niches and diversities of resource base. Need for institutional and other logistic support to complement the technologies hardly needs mention. The link between specific technological measures and conditions associated with sustainability indicated in Table 4, is briefly commented upon here.

Resource-Centred Research and Technologies

For the enhancement of input absorption capacity and use intensity of fragile resources, both mechanical and biological measures can be employed. Traditionally, people treated fragile resources through measures such as terracing, trenching, ridging hedges and shelterbelts etc, and made them usable. With better scientific understanding of the precise interactions between resource components and specific treatment variables, new and more effective options can be evolved to handle the problems of slope, drainage, marginal soils, and excess or deficit moisture [Dregne 1983, and El-Swaify et al 1985]. Plants with high soil binding and soil building capacities can also form important components of new technologies. Integrated use of (i) early maturing, fast growing, ratoonable perennials (including trees and shrubs) and (ii) photoperiod insensitive, early maturing, high yielding annuals, can be an important step for increased resource use intensity. Species with high productivity and high value, suited to fragile resources, can enhance their input absorption capacity in economic terms [Nair 1983 and Walker 1987]. With focused screening of the available vast and diverse germplasm, it should be possible to identify several species with the above mentioned attributes.

It should be noted that a number of resource-centred technologies, being developed at present, implicitly focus on some of the above issues. But these initiatives, be they pasture development through reseeding or soil manipulation etc, or more publicised and subsidised initiatives such as integrated watershed development, are highly 'technique' dominated, and they are still conceived and implemented in 'project mode'. The institutional factors and user perspectives are almost completely neglected, and this reduces their relevance to the problems of these areas [Blaikie and Brookfield 1987].

Although, due to resource heterogeneities, the location specificity of technologies cannot be avoided, any emphasis on wide adaptability of technological components can facilitate wider coverage and/advantage of scale to specific production activities in fragile resource-agriculture.

Systems Approach

Suggesting a greater need for a systems approach of R and D for fragile resource-agriculture amounts to stating the obvious. Yet, to avoid the gaps characterising the conventional approach, a few issues need to be mentioned specifically.

Diversification and interlinkages of different land-based activities have been the major strengths of traditional farming systems. The linkages can be seen between the activities based on annuals and perennials; intensive and extensive resource uses; and complementary uses of common property resources and private property resources [Jodha 1988]. Diversity and implied linkages are important considerations in the choice of crops and their attributes. Moreover, in such systems, productivity and stability of the total system, rather than that of individual components, is emphasised. Modern science and technology is endowed with several elements which can strengthen the linkages and components indicated above. On some of the individual components, considerable work has been done. Research on upland crops and mountain horticulture, as well as coarse grain crops and rangelands in the dry tropical areas, has received considerable attention both at national and international levels [York 1988 and Jodha 1989b]. Efforts to impart a farming systems' perspective to R and D have also been made [IARCs 1987]. Yet, the major gap in the past R and D has been the absence of integrated focus. The latter alone can help diversified and interlinked systems of resource use and production.

Strengthening Resilience

Diversification, flexibility, and interlinkages among different production activities, input use practices, and consumption patterns imparted a degree of resilience to the traditional farming systems in the fragile areas. Resilience of the system was also strengthened by factors such as periodic release of pressure through migration or transhumance; a variety of input and product recycling devices; collective sharing systems; and informal regulatory measures to ration the use of fragile resources. Except for a few institutional devices, most of the above measures can be strengthened by the new technological components. To achieve the above goals, the focus of R and D will have to be on diversification, flexibility, and local resource-centred interlinked activities. Again, the availability of genetic material of diverse attributes as well as improved knowledge and the capacity to precisely understand interactions between different biophysical variables, offer significant opportunities for the development of options to satisfy the above goals [Dregne 1983; Serrano 1984; York 1988; Jodha et al 1988; and Ruttan 1989].

Inter-Regional Linkages

Inter-regional linkages, as mentioned earlier, help in sustainability by relaxing internal constraints and facilitating exchange of local surpluses. Under traditional systems, fragile areas had their linkages with other regions largely through harnessing of specific niches and petty trading, unequal exchanges based on large-scale extraction of their resources (e g, timber from the hills), and periodic migration and transhumance. Such links did help in survival, but are inadequate for sustainability implying enhanced performance to meet the increasing demands over time.

The physical and market-based linkages between different regions are a function of the combination of several factors, some of which fall far outside the area of agricultural R and D. However, one of the basic factors promoting inter-regional exchange is the relative difference in the comparative advantages enjoyed by different regions in specific activities and products. The fragile areas under question, as mentioned earlier, also have some activities and products that have comparative advantages in relation to other regions. Agricultural R and D can help the fragile area by identifying such activities and products and improving their quality and productivity. In the past, however, this sort of complementarity between the fragile regions and the other regions did not receive sufficient attention [Jodha 1988].

TABLE 4: AREAS OF FOCUS R AND D FOR SUSTAINABLE AGRICULTURE IN FRAGILE RESOURCE ZONES

Areas/Issues of Focus	Potential Enhancement of Sustainability Through:			
	Resource Use Intensity	Input Absorption Capacity	Resilience and Productivity	Inter Systems Linkages
Resource centred R and D:				
Physical/biological measures to manage: slope, drainage, soil, moisture etc	x	x		
Soil binding/building plants/crops	x	x		
Perennials (fast growing, early maturing, high productivity, high ratoonability)	x			
Biological control of yield reducers		x	x	
Locally renewable resource focus	x		x	
Location specificity		x	x	
System oriented R and D:				
Linkage of product and resource centred options			x	
Diversified-interlinked activities: (Annual-perennial plants)	x		x	
Extensive-intensive land uses	x		x	
R and D focused to harness niches and diversity:				
Wider adaptability of options			x[a]	x[a]
Focus on productivity of total system			x	
Flexibility in input use/agronomy			x	
Recyclability/storability			x	
Complementarity with other zones (related to input, product, value additions)				x
Input of folk knowledge			x	x
Infrastructural/institutional and resource support[b]			x	x

Notes: a Gains through advantage of scale and replicability of external experience.
b Options under this category may not directly relate to R and D.

V

Conclusion

The prospects of sustainability for agriculture in the fragile areas are severely constrained by the specific features of their natural resource endowments. Sustainability, or rather survivability, in a situation of low pressure on resources was possible through traditional land extensive practices. In the changed circumstances with high pressure on fragile resources, the required high resource use intensity (for high productivity) with conservation is not possible through traditional measures. This requires application of modern science and technology blended with the rationale of indigenous practices. Various areas of focus for R and D are indicated to achieve this. Any progress in the suggested direction, however, will depend on the reorientation of agricultural research strategies to suit the specific requirements of these areas. This in turn is largely an institutional rather than a technological problem. The major implication of this conclusion is aptly summed up by Rhoades [1988], when he recommends the policy-makers in mountain areas to start "thinking like a mountain". The same applies to the other fragile areas. Accordingly, the fragile area-development strategies, to be meaningful and effective, should have a strong "fragile area-perspective". Discussion on this aspect forms a part of the author's ongoing work on the institutional imperatives of sustainable agriculture in the fragile resource zones.

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