**International Symposium**
**Sustaining Food Security and Managing Natural Resources in Southeast Asia**
**- Challenges for the 21st Century -**
January 8-11, 2002 at Chiang Mai, Thailand

# Implications of Land and Water Degradation for Food Security, with Particular Reference to Asia and Africa

**Frits Penning de Vries[1], David Molden[2]**

**[1]International Water Management Institute, Southeast Asian Office, P.O. Box 1025, 10903 Jatujak, Bangkok, Thailand, f.penningdevries@cgiar.org**
**[2]International Water Management Institute, P.O. Box 2075, Colombo, Sri Lanka, d.molden@cgiar.org**

## 1 Introduction and Rationale

### 1.1 Degradation of Land and Water, Shortages of Water and Land

It is a common fallacy that land is ample and indestructible, and that clean water rains on us every day. Loss and degradation of these natural resources is widespread, particularly in developing countries. The reality is that this degradation threats our future and that of our children.

Another common mental image that is that of gradual change: that degradation proceeds slowly and can be reversed, slowly, with adequate inputs. Yet, agro-ecological systems and societies are resilient only up to a threshold, and collapse when pushed too far. The rates of natural resources degradation may seem slow to some, but this should not lull us into complacency.

Land use does not necessarily lead to degradation, not even intensive land use. Proper short term investments in inputs (water, fertilizer, seeds) and long term investments in structures and equipment (pumps, tractors, dams, terraces) can conserve soil and water, while allowing productive and sustainable agricultural land use. The same applies to water: its use for growing crops does not have to lead to shortages and pollution. However, if conditions are such that farmers cannot invest in these inputs and structures, human activity will continue to degrade natural resources and peoples livelihoods, unless off-farm employment can help provide an income without destroying the natural resource base. Societies and its institutions should invest for the long term in water and land management structures and in education to halt degradation.

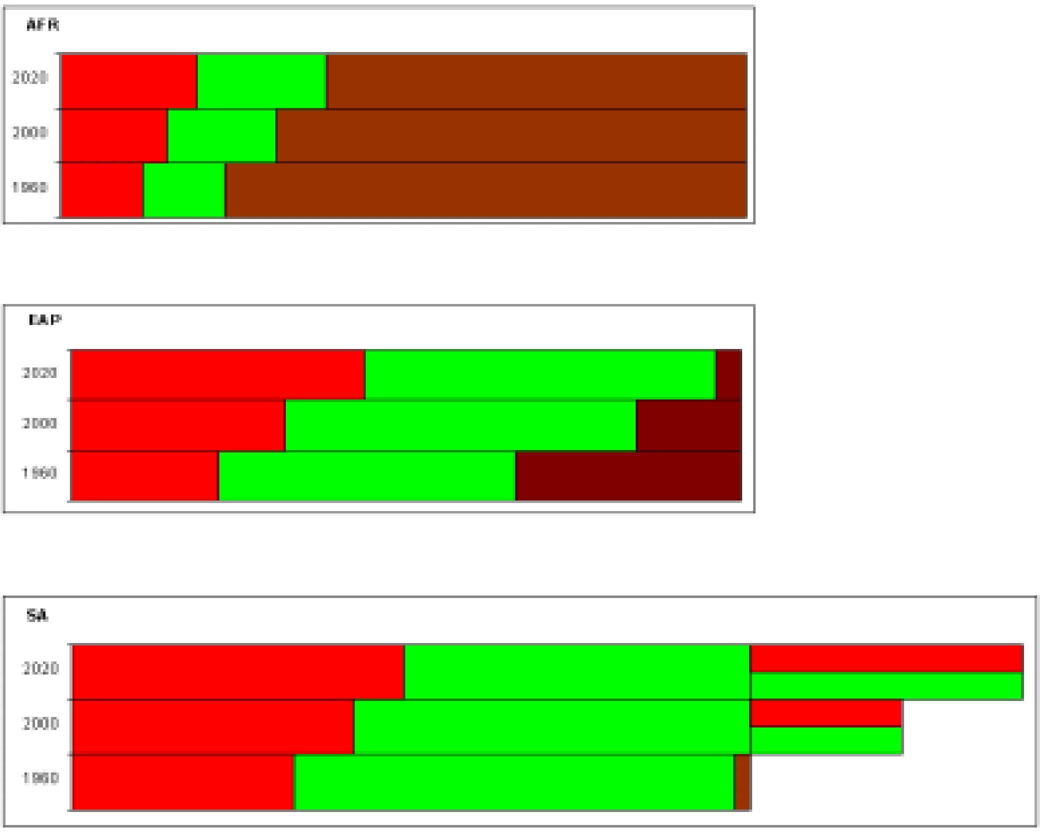
Among the many consequences of degradation are the local reduction in household food security and in the quality of livelihoods, the threat of losing the capacity for achieving national food security, the high cost of maintaining or restoring natural environments (parks, wildlife reserves, wetlands), the loss and devaluation of land for agricultural purposes, and the increased risks of natural disasters (flooding and drought).

For ‘land’, degradation is a well-known process (e.g. Bridges et al., 2001). For ‘water’, it is more common to speak of depletion and pollution of water resources rendering it unavailable for agricultural and non-agricultural uses. Figures 1 and 2 present one view of each. It is estimated that as many as 1.8 billion people live in areas with some noticeable land and water degradation, and which reduces livelihoods and household food security. Degradation occurs in some or many parts of nearly all developing countries. Moreover, the rate of degradation of land and water resources is accelerating, and consequences for food security are becoming increasingly clear (Wood et al., 2000).

## 1.2 Declining Land Resources for Food Production.

The extent and rate of land degradation is captured in Figure 1 below for three regions: East Asia and the Pacific (EAP), South Asia (SA) and Africa (AFR). The full length of the bars represents the surface that 5000 years ago could have been turned into good farmland. Since then, people have degraded land irreversibly but opened up new land as well, not unlike in ‘strip mining’. The barchart shows the fraction of land suitable for sustainable agriculture that is still available in brown (black, on the right side of the bars), the land currently in agricultural use in green (light grey), and the area fully degraded where recovery is uneconomical in red (dark grey). Three dates are shown: the lower bar depicts the situation in 1960, the middle one the current situation, and the upper one scenario for the near future; the bar is split green/red (light grey/dark grey) when more land is ‘used’ than is ‘available’ for sustainable agriculture. (Source, Penning de Vries, 2001). The red part reflects the area where ‘land’ has a big influence on ‘water’, and the green part reflects where ‘water’ has a major influence on ‘land use’.

**Figure 1 Declining land resources for food production**



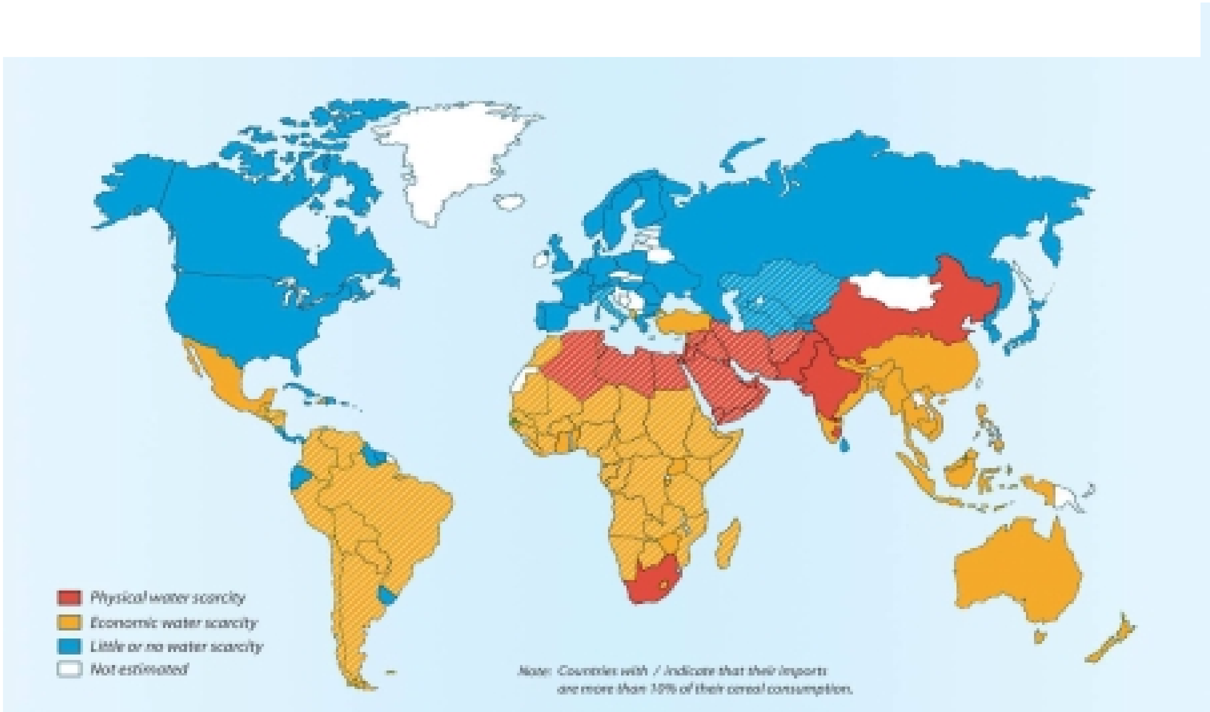

## 1.3 The Projected Water Scarcity in 2025.

Figure 2 shows a global and first approximation of areas of projected water scarcity for biophysical or for economic reasons for 2025. Note that at any level of supply, there will be large fluctuations in time and space, making that this map is less significant for household water security than for the national average. (Source: IWMI, 1999.)

Degradation of water and of land often occurs in parallel and both lead to a lower level of ecosystem services, in particular a reduced capacity for food production and income generation. Both are the result of inappropriate management. The degradation of these resources needs to be addressed as one problem and they are treated jointly in the remainder of this document.

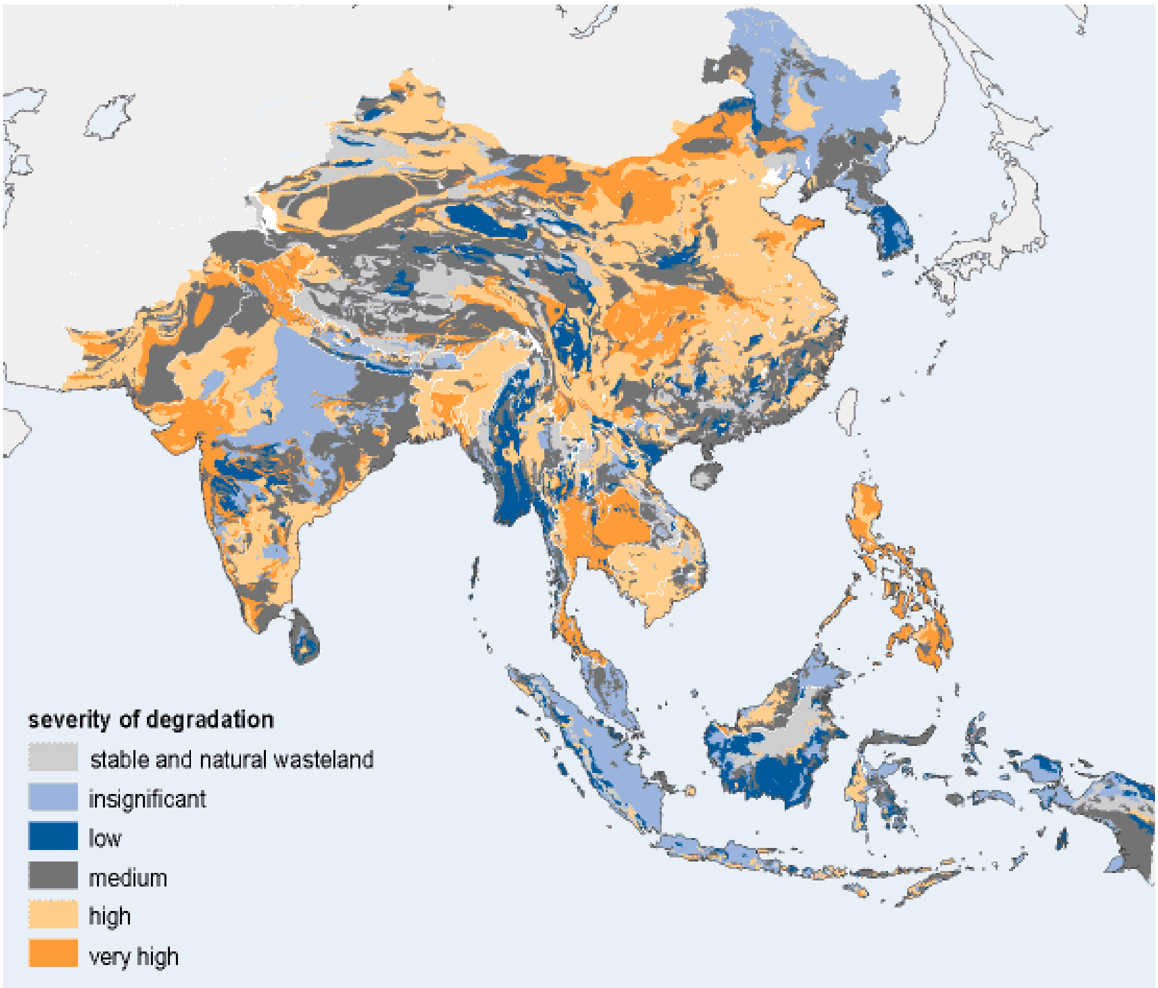
Soil degradation has become globally a common phenomenon, but its extent varies between 'loss of the natural resources' and 'insignificant, or even rehabilitation. Figure 3 shows a specific example for South and East Asia. Both indicate that degradation is widespread, and that its spatial variability is quite pronounced at the larger scales. At smaller scales of farms and catchments, heterogeneity is also a very significant factor. Heterogeneity contributes significantly to problems of scientists (how to handle it) and to solutions for rural people (by providing more options for development than the ‘average’ would suggest).

**Figure 2 Projected water scarcity in 2025**




Source: IWMI,1999

**Figure 3 Global land degradation assessment for South and East Asia.**




.

Source: Van der Lynden and Oldeman,(1994).

## 1.4 Impact on Food Security

Even though land degradation is often visible and water shortage reported daily in the press, it is difficult to translate these phenomena into consequences for food security is difficult conceptually and in practice. For subsistence farmers, consequences are direct: less food with more efforts, and even: moving out. But nowadays, most farming households, however, do take part in food trade. As producers of food, degradation leads to lower yields with more efforts, so: either less food or less income. As consumers, they can buy food if they have money. Degradation may also leads to increased cost of living and to higher food prices. So household food security is affected also in the second case, albeit in a more complex manner. In fact, the relation between degradation and food security is of enormous complexity due to the interactions between land, water, populations and wealth, and the rapid changes therein.

There are strong indications that consequences of degradation for food security at the household level already affect many people significantly (e.g. Bridges et al., 2001, Scherr, 2001). Global food security, on the other hand, is not affected much, yet. Food security in this document implies the production of food, the access of food, and the utilization of food. For global food security, the emphasis is that sufficient food is produced in the world to meet the full requirements of all people: total global food supply equals the total global demand. For household food security, the focus is on the ability of households, urban and rural, to purchase or produce food they need for a healthy and active life; disposable income is a crucial issue. For national food security, the focus is on sufficient food for all people in a nation; it can be assured through any combination of national production and food imports and exports. Food security has always a component of production, access, and utilization. Women are typically the gatekeepers of food security.

Land and water degradation has also other major effects. The Asian Development Bank (1997) expressed its concern about environmental degradation and future food production). The current economic crisis places additional emphasis on short term economic concerns over longer term environmental concerns. One recent estimate of the cost of remediation of environmental damage due to degradation for Asia puts it 35 billion US$ (Table 1). Though very roughly estimated, the order of magnitude indicates a marked need to address erosion problems, and calls attention for land degradation and for assessing future directions for rehabilitation by reforestation and other means. Such views are supported by many (Gregory et. al., 2001).

## Table 1 Annualized cost of remediation for Asian countries (in million 1990 US$)

| Country[a] | Water[b] | Air[c] (erosion) | Land[d] (MSW) | Land[e] | Land[f] (forest) | Land (Total) | Eco-system[g] | COR (Total) | COR/GD (%) | Rank based on OR/GDP |
|---|---|---|---|---|---|---|---|---|---|---|
| **Bangladesh** | 13.70 | 30.34 | 199.21 | 99.87 | 22.38 | 321.47 | 52.39 | 417.89 | 1.95 | 8 |
| **Bhutan** | 0.16 | 0.35 | 8.07 | 0.43 | 0.00 | 8.50 | 24.45 | 33.45 | 14.93 | 19 |
| **Cambodia** | 0.31 | 0.70 | 72.84 | 5.26 | 0.00 | 78.11 | 30.85 | 109.97 | 5.62 | 16 |
| **Lao PDR** | 0.26 | 0.58 | 34.19 | 4.27 | 0.00 | 38.46 | 33.18 | 72.48 | 7.43 | 18 |
| **Mongolia** | 5.91 | 13.08 | 2,517.62 | 6.14 | 249.50 | 2,773.26 | 13.39 | 2,805.64 | 397.63 | 20 |
| **Myanmar** | 3.56 | 7.87 | 208.42 | 52.32 | 0.00 | 260.74 | 65.20 | 337.36 | 1.23 | 4 |
| **Nepal** | 0.78 | 1.74 | 93.10 | 12.43 | 10.07 | 115.60 | 48.90 | 167.02 | 5.32 | 15 |
| **Pakistan** | 53.97 | 119.49 | 522.59 | 187.21 | 157.40 | 867.20 | 36.09 | 1,076.76 | 2.57 | 12 |
| **Sri Lanka** | 3.50 | 7.76 | 46.84 | 18.28 | 0.00 | 65.12 | 147.86 | 224.24 | 2.54 | 11 |
| **Vietnam** | 12.97 | 28.71 | 134.56 | 66.19 | 0.00 | 200.75 | 251.48 | 493.91 | 7.30 | 17 |
| **People's Rep. of China,** | 1,430.13 | 3,166.07 | 9,939.10 | 1,648.85 | 1,070.02 | 12,657.97 | 299.79 | 17,553.96 | 4.88 | 14 |
| **India** | 418.97 | 927.53 | 3,630.67 | 1,092.80 | 159.51 | 4,882.97 | 852.23 | 7,081.70 | 2.89 | 13 |
| **Indonesia** | 100.10 | 221.61 | 675.93 | 277.99 | 0.00 | 953.92 | 296.30 | 1,571.93 | 1.43 | 7 |
| **Papua New Guinea** | 1.73 | 3.82 | 9.61 | 3.33 | 0.00 | 12.94 | 70.44 | 88.92 | 2.39 | 10 |
| **Philippines** | 39.59 | 87.65 | 184.76 | 134.91 | 0.00 | 319.67 | 160.67 | 607.57 | 1.40 | 6 |
| **Thailand** | 67,00 | 148.32 | 477.85 | 68.03 | 11.75 | 557.63 | 47.73 | 820.68 | 0.83 | 3 |
| **Fiji** | 0.52 | 1.16 | 6.03 | 1.45 | 0.00 | 7.48 | 20.37 | 29.53 | 1.97 | 9 |
| **Korea, Rep. of** | 199.84 | 442.41 | 43.82 | 159.42 | 0.00 | 203.24 | 61.71 | 907.19 | 0.33 | 2 |
| **Malaysia** | 43.15 | 95.52 | 98.23 | 40.55 | 0.00 | 138.78 | 329.48 | 606.93 | 1.32 | 5 |
| **Singapore** | 24.42 | 54.07 | 0.02 | 14.40 | 0.23 | 14.65 | 14.55 | 107.70 | 0.24 | 1 |
| **Total** | 2,420.58 | 5,358.76 | 18,903.45 | 3,894.14 | 1,680.85 | 24,478.44 | 2,857.06 | 35,114.83 | | |

Source: Jalal and Rogers (1997).

Notes to Table 1:

a Data for Afghanistan, Maldives, South Pacific (including Marshall Islands), Hong Kong and Taipei, China are incomplete or unavailable.

b Cost data based on 90% reduction of COD, suspended solids, and some heavy metals for PRC are used and the total CORs of all the DMCs are assumed proportional to their total commercial energy consumption.

c Cost data based on 90% reduction of TSP and sulfur emissions for PRC are used and the CORs for all the DMC are assumed proportional to their total commercial energy consumption.

d Unit cost data per ha are derived from PRC and total area subject to erosion for all the DMCs is estimate assuming it is proportional to their total cropped and pasture areas. It is further assumed that 70% eroded area will be controlled to achieve 70-95% erosion reduction in ten years.

e A fixed waste generation rate, 0.21 per capita per year, and fixed costs for waste collection and waste management $20/t for collection and $2/t for sanitary landfill, are assumed for all DMCs. Only urban municipal solid waste (MSW) are considered.

f PRC cost for tree plantation of $179 per ha is adopted and a universal target of 20% forest coverage rate is assumed for all DMCs. If a country's forest coverage exceeds 20% no further cost is incurred.

g Indonesia's unit costs is building and running national parks and targets for the period 1991-2000 are used for all DMCs, assuming the cost is proportional to the total number of species considered threatened, including mammals, birds, reptiles, amphibians, higher plants and fishes.

# 2 Driving Variables and Options to Influence these

## 2.1 Driving Variables.

Ultimate driving variables of degradation include population growth and its increase in wealth, globalisation of trade and economic relations, and climate change. These have an enormous momentum and are slowly to modify. We will focus on intermediate driving variables the are closer within reach for action.

Rather than discussing the driving variables by continent or by biophysical process, we analyze situations in four broad geographical zones, following the flow of water, in: 'headwaters', 'plains', cities and peri urban areas' and 'coastal areas'. Areas within these zones but in different countries have much similarity in the degradation processes and in the causes there off. The fact that the zones are generally also connected gives rises to another set of issues where use in one area affects use in another. There are major flows of water and plant nutrients between them, generally towards cities and the sea. Movement of people and trade are other example of significant interactions between zones. The main document covers the processes, causes and impacts of particularly soil erosion, nutrient depletion, water pollution, groundwater depletion, and river desiccation**.**

In headwaters, typically the upper and upland parts of river basins, degradation often starts in shifting cultivation ('slash and burn'), and in fewer cases as logging operations. Particularly the last 50 years has seen much encroachment in many countries and in all continents due to population growth, migration and relocation of people, and due to absence of effective laws and/or control measures. Encroachment is a continuing process, and an increasing number of marginal areas (steep slopes, poor and shallow soils) are subject to these human activities. Erosion is an important degradation process. Another major driver is that yields on already cultivated areas in headwater areas are not growing fast enough to keep up with population growth and increasing food needs. Farmers have to expand their crop area to keep up. The cause is often insufficient intensification due to lack of appropriate and profitable technologies, and suitable markets. Interestingly, there are also situations (Mediterranean, Philippines) where the reduction of the number of farmers has lead to degradation, namely when maintenance of structures (terraces, irrigation channels) becomes compromised.

The principle driving variable of land and water degradation in Plains is the intensification of agriculture, through an increased and often inappropriate application of fertilizers, water and pesticides. Over- or under-use of water, fertilizers and pesticides cause the problems. Intensification requires extra water, either from surface irrigation or groundwater. When misappropriated, this leads to problems (groundwater overdraft, soil salinization, pollution, dessication). Insufficient use of fertilizer leads to nutrient depletion, a very common degradation process in marginal areas. Lack of knowledge of the consequences of decisions at the farm level, district and national level, and lack of incentives to use natural resources more carefully, are behind these choices. In some cases, there is a lack of technologies to use natural resources effectively and without degradation. One of the difficulties in arresting agricultural pollution is that farmers see little benefit for changing their practices. This is often because of inappropriate policies, including underpriced water and fertilizer, and pesticide subsidies. A second difficulty is the dispersed nature of non point source pollution – substantial agricultural pollution is the result of the actions of several farmers, and the entry point into the hydrologic systems is widely dispersed. This poses also severe technical monitoring problems.

The driving variable in urban and peri-urban areas is the intensive use of resources. As cities grow and many inhabitants become more affluent, the driving force is expected to get stronger in the coming decades. This is because the intensity of using food and water in these areas is much higher than in the other geographic regions, and the capacity for natural restoration is much exceeded, or sometimes even destroyed (e.g.: city canals are ‘dead’). Excessive withdrawal of groundwater leads to subsidence, and much economic damage. Another form of 'degradation' of land in cities and peri urban areas from an agricultural perspective is the expansion of infrastructure (houses, roads, industrial areas, golf courses) to accommodate the growing number of people and their needs for transport and recreation. This process consumes annually about 0.5% per year of prime land. Soil and water pollution is due to import into urban and peri-urban areas of huge quantities of food and feed (Faerge etal., 2001), the waste of which is often not properly disposed of. Lack of recycling of water and solid waste is common. The serious health issues require establishment of clear standards and a proper monitoring of produce quality.

In coastal areas, the driving force is growth is encroachment and the off site effects from plains (pollution, desiccation) and headwaters (erosion). As much as 39% of the world's population live within 100 km of the coast, and their presence, and growth in wealth, has a major impact. Shoreline modification has altered sea currents and sediment delivery mechanisms. Artificial mechanisms for shoreline stabilization replace the natural buffering capacity of natural systems such as coral reefs or estuaries to protect against storms. Rising waters affected by climate change can potentially have dramatic impacts on coastal areas. Coastal areas are at the receiving end of upstream land and water degradation processes – these zones receive the sediment loads and pollution transported by water from upstream agriculture and cities. These areas must also absorb changes brought about by reduced river discharges and changes in the discharge downstream hydrograph brought about by upstream development. In addition, high populations put pressure on coastal and marine environments, and encroachment occurs in fragile wetlands and coastal areas.

## 2.2 Choosing Between More or Less Degradation

With few exceptions, people do not intend to degrade the natural resources they use, but their decisions to do so are guided by economic realities and lack of understanding. It is therefore that we focus on those realities and on providing knowledge.

We focus at the crucial clusters of driving variables that operate in the different geographical areas we distinguished, albeit with different intensities. In a sense, this will be nested sets of driving variables. Policy makers influence the socio-economic environment for land and water users, who are then guided in their decision making and will undertake actions that co-determine their food security and degradation of natural resources. Because of the complexity of nearly every process and the multiple levels of driving variables, changes in either driving factor may be essential, yet none is sufficient by itself.

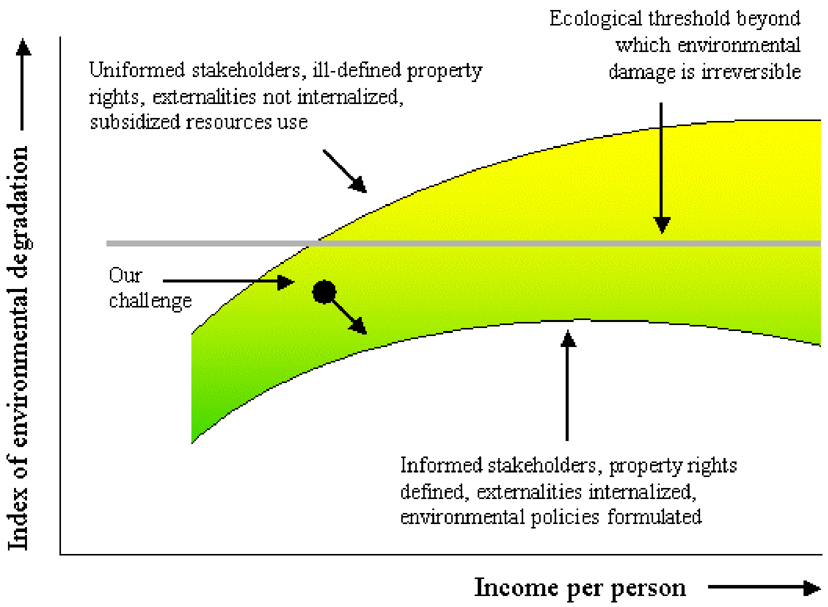
Successful approaches to reducing degradation and improving food security consider how to make best use of, or increase, all resources that people should have at their disposal: natural, human, physical, social, financial resources. Participatory means ‘with the people’: designing and implementing intervention strategies should occur together with all stakeholders.

### 2.3 Attitudes and Incentives: Concern for and Knowledge about Natural Resources

A recent article in The Economist (August 2001) expresses optimism that societies become aware and concerned about degradation of the natural environment, and with rising incomes find ways to halt and reverse degradation, and provides some interesting examples from Europe and North America. We consider this view overly optimistic. If lack of ‘green’ concerns in a societies and lack of equity, that would keep most people at low income levels even though the national average rises, damage may be much higher than the average at any income level. If the land and water resources are exploited beyond their threshold of resilience, due to high population density or ecological fragility, the system breaks down rather suddenly. That case, in a short period land gets lost for agriculture, water is no longer productive, national food security is reduced, and the option for income generation through agriculture disappears. These two contrasting possible outcomes are depicted in Figure 4.

To bend the trend from increasing environmental damage and degradation to rehabilitation (arrow), governments and others have to generate more public awareness and create options for environmental friendly actions. Research organisations and enterprises encouraged by donors, can facilitate the change by making investments technically more effective (‘more crop per drop’), cheaper, and more accessible.

**Figure 4** **Possible levels of environmental damage in relation to income, and the direction of development this paper promotes to steer towards minimum degradation.**




Source: Adapted from ADB (1997, pg 214), and IBSRAM (1999).

Increased public awareness of the state and importance of natural resources is crucial. Newspapers and television, environmental education at school and ‘green activists’ play important roles. Awareness of the many technological options for land and water management whose effectiveness has been proven is still quite limited. Limited awareness is also due to incomplete or even incorrect mental pictures among land and water users about natural resources, and the public at large**.**

It is important to have a legal framework to define what activities are allowed in a particular area, who is responsible for them and for the state of the resources, and who oversees. It is also important that the legal framework is effectively implemented; internationally accepted standards are needed on maximum contamination of soil and water used for different purposes.

Within the arena of laws and politics, one of the most important issues is to provide smallholders with tenure or long term arrangements on land use, and water users assured rights to this resource. The absence of such rights are an important threshold for farmers to mobilize funds and invest them in their farms, improving livelihoods and reducing degradation. Assuring long term rights to land and water is probably the single most important action that can halt degradation and assure poor people of a decent option to earn a living through agriculture.

Policy interventions that seek to overcome environmental problems in agriculture need to be based on a proper understanding of why farmers degrade their environment. Why, for example, do farmers often seem to overgraze rangeland, deplete soil nutrients and organic matter, and overuse irrigation water, pesticides and nitrogen, when these actions cause health problems and reduce future incomes for themselves, their children, and the communities in which they live? The answer lies with the incentives facing farmers. Farmers are not irrational. On the contrary, they maximize income and minimize risk in a dynamic context and often under harsh conditions and serious constraints. They degrade resources when there are good economic and social reasons for doing so, i.e., when the benefits they obtain exceed the perceived costs that they, as individuals, must bear.

## 3 Further Developments of Technology and Management

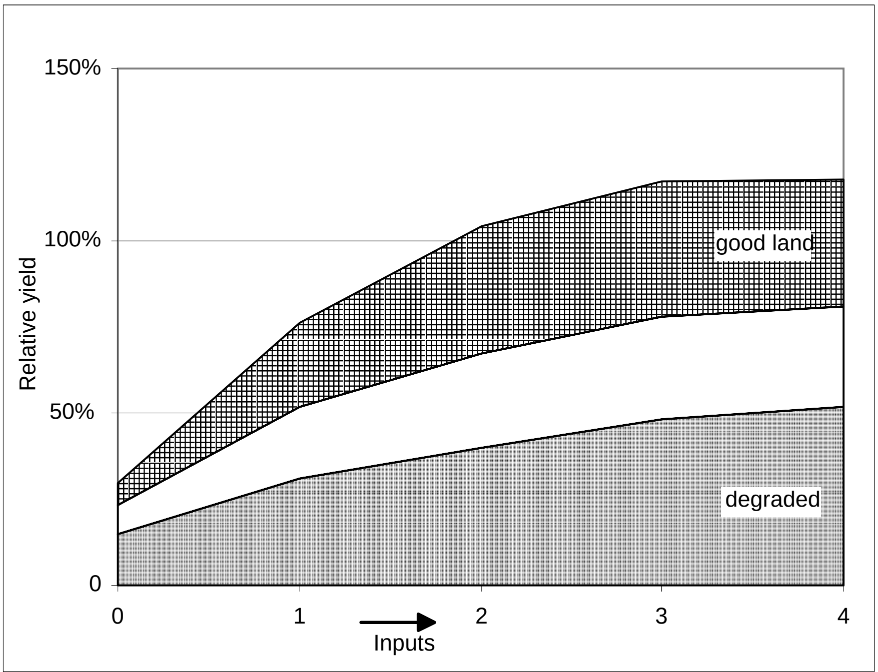
With respect to land and water management, technological developments have led to (1) higher crop and livestock yields per unit of land and water (selection, breeding, biotechnology), (2) replacement of human and animal labour by machines (e.g. tractors) allowing individuals to cultivate larger areas, (3) increases in the volumes of accessible irrigation and drinking water (e.g. reservoirs, diversion structures, pumps), (4) replacement of human observations by readings of instruments for more consistent management (e.g. soil probes that trigger irrigation when the soil is dry), (5) refinement of management to produce the same output or more with less inputs and reduced risk (e.g. precision agriculture, drip irrigation, weather forecasts).

Like any biophysical process, crop productivity per unit of input has a ceiling level. Given the major advances in the past decades, one might ask whether there still is any potential for developments in technology that bring significant improvements in land and water productivity. Since maximum biological efficiencies of crop and livestock production are reached in only few cases, it is likely that still many technological and management inventions can be realized to do more with less inputs, more recycling, less waste and pollution. However, spectacular increases in productivity over the past decades makes that some production systems have become very efficient indeed. The downside is that in areas with already high land and water productivity, further increases in productivity will be increasingly difficult to attain (e.g. Cassman, 2001).

Farming systems based on ecological principles do a better job, generally, in generating and recycling organic matter and plant nutrients, and in protecting natural resources, than many modern but unbalanced systems. This includes use of tree-based land use on hillsides. Technology improvements for NRM should be more than just input/output efficiency.

A general way of seeing what technology can contribute to rehabilitation of degraded land is shown in Figure 5: increasing the maximum level of production (increasing the yield gap, making improvement by farmers easier), increasing yield stability (i.e.: reducing the relative level of risk), and improving the economic returns to investment (by increasing the efficiency of the response to inputs, particularly at lower yield levels).

**Figure 5 Two hypothetical sets of curves of crop yield in rainfed conditions as a function of the level of inputs (labour, water, fertilizer, crop protection)**




The set on degraded land shows lower maximum yields, reduced input efficiency and higher risk.

Carbon-sequestration, desirable from the point of view of reducing climate change, is also a feature of reduced land degradation: the more Carbon (C) is retained in SOM*, the better its fertility, water holding capacity, and resilience. Increasing the C-content of the soil by 1% on 1 ha would eliminate 3 t C from the air, albeit that plants need to transpire some 6-12000 t water to fix this C and depose it in the soil, water that will not run to the river. This suggests that C-sequestration in humid and sub-humid areas, where the lower value applies, has a lower risk of leading to water conflicts than in semi arid areas.

### 3.1 Infrastructure

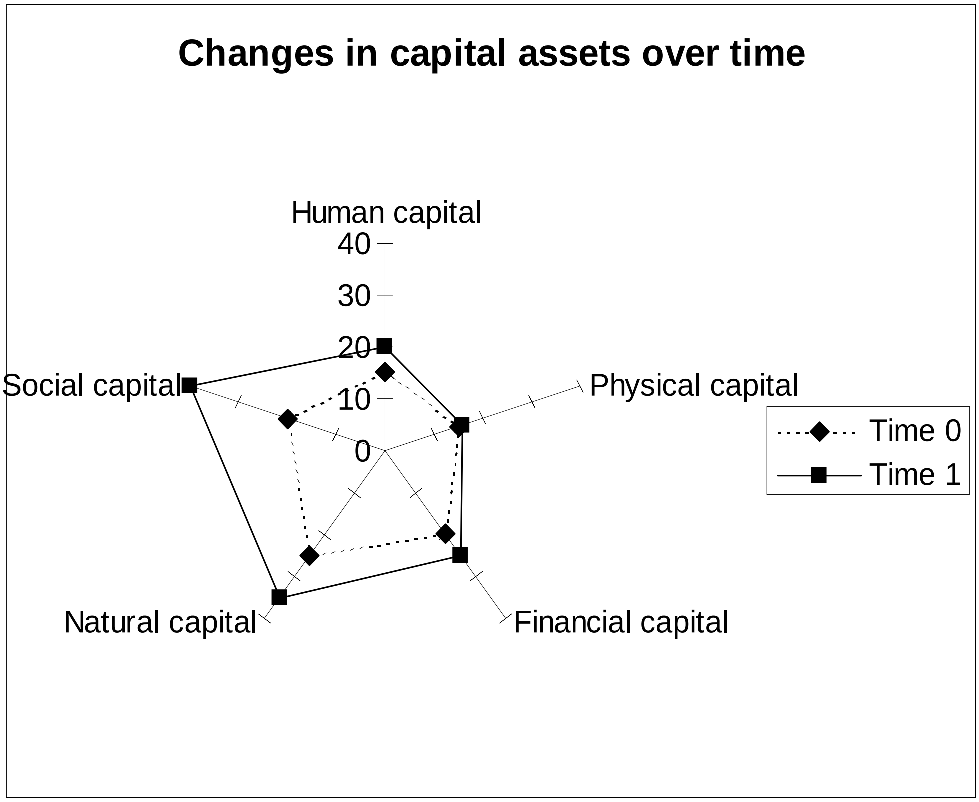
Human development brings majors expansion in infrastructure: roads, channels, housing, dams, airports, recreational facilities. It can have some very positive effects too by making key inputs available and at lower prices (e.g. fertilizer), by giving farmers more options for increasing income and hence relieving the pressure on land (e.g. high value vegetables and livestock products, even forest and tree products), and by facilitating more commuting and non-farm activities).

Yet, infrastructure is often laid out on good agricultural land, hence diminishing the amount of land available for food production. New infrastructure can rapidly accelerate degradation. Roads, and even footpaths, are important contributors to erosion/sedimentation. As for water, generally, infrastructure increases its availability, by channelling it to places where it is most needed (often for non-agricultural use) and reducing leakage and improving recycling**.**

The low cost of transport by road and sea allows transport of large amounts of food from rural areas to cities, from export countries to importing ones, and from one continent to another. The driving force is generally the difference in cost of production between the locations, and produce quality. Wealthy people, particularly in urban conglomerates, use resources from a large area to produce food and the many other things they consume. This (non contiguous) area has been labelled ‘Ecological Footprint’ (..), parts of which may be far away. As for the overall utilization of water, the phenomena reduces global water consumption if the water use efficiency is higher at the export site. For the current major food exporters, USA, Brazil, France, and major importers, China, African countries, this may actually be the case, given the different climates. Water transport in food is negligible. Not negligible is the amount of ‘plant nutrients’ transported in food across large distances. Yet, there are no mechanisms to ensure recycling to the source of origin, and this process contributes strongly to 'nutrient depletion' in the Plains. Not addressing this ecological principle undermines global sustainable land and water management**.**

Widespread promotion of 'best practices' is an excellent way to make use of experiences obtained elsewhere, provided that these experiences were evaluated from the viewpoints of the five dimensions for evaluation of the sustainability of agricultural production systems (Smyth and Dumanski, 1993, Coughlan and Lefroy, 2001): productivity, stability, protection of the natural resources, economic viability, social adoptability. Alternatively or in combination, they could be assessed according to their impact on capital assets (financial, natural, social, human, physical) of INRM. Figure 6 gives an example of a holistic evaluation of a new technology.

**Figure 6 The Spider Web (radar) Diagram**




Source: cf. Campbell et al., 2000.

The spider web (radar) diagram shows how, on a relative scale, a new technology is changing a previous practice, along five dimensions. The example in the figure illustrates that the asset that has shown much change is that of social capital, while physical and financial capital have hardly altered

## 4 Acknowledgements

This document draws on a document being developed for GEF through by a review of literature and draws heavily on expert knowledge inputs from IWMI, other CGIAR-institutes and their partners in Integrated natural Resource Management research, World Bank staff and other individuals. GEF provided guidance and the overall framework for the document.

## References

Asian Development Bank. 1997. Emerging Asia, changes and challenges. ADB, Manila, Philippines (350 pp).

Bridges, E. M., I.D. Hannam, L.R. Oldeman, F.W.T. Penning de Vries, S.J. Scherr, and S. Sombatpanit (Eds.) 2001. *Response to land degradation*. Science Publishers, Inc.

Burke, L., Y. Kura, K. Kassem, C. Revenga, M. Spalding, and D. McAllister. 2001. *Pilot analysis of global ecosystems: Coastal ecosystems*. Washington, DC., USA: World Resources Institute.

Campbell, B., Sayer, J., Frost, P., Vermeulen, S. Ruiz Perez, M., Cunningham, A., Prabhu, R., Waddington, S., Chuma, E. 2000. Evaluating the Impacts of Integrated Natural Resource Management (INRM) Research. Paper presented at the INRM workshop in Penang, 2000. http://www.inrm.cgiar.org/documents/workshop_2000.htm

Coughlan, J.K. and R.D.B. Lefroy. 2001. Assessment of sustainable land management using the FESLM: The IBSRAM experience. Issues in Sustainable Land Management No. 8. Thailand: International Board for Soil Research and Management.

Drechsel, P., D. Kunze, and F.W.T. Penning de Vries. 2001. Soil nutrient depletion and population growth in Sub-Saharan Africa: A Malthusian Nexus? Population and Environment: 22, 4.

Drechsel, P., and D. Kunze (Eds.) 2001. *Waste composting for urban and peri-urban agriculture: Closing the rural-urban nutrient cycle in Sub-Saharan Africa*. CABI Publishers.

Greenland, D.J., G. Bowen, H. Eswaran, R. Rhoades and C. Valentin, 1994. Soil, Water, and Nutrient Management Research, a new agenda. IBSRAM Position paper, IBSRAM, Bangkok, Thailand (60 pp).

Jalal, K.F. and P.P. Rogers, 1997. Measuring Environmental Performance in Asia. ADB Environment Paper No. 13. Asian Development Bank, Manila, Philippines.

IBSRAM, 1999. Medium Term Plan. International Board for Soil Research and Management, Bangkok, Thailand.

Peng, Keshan and Zhenzing Xu. 1993. *The problems existing in land environment of China protective countermeasures. Ecological Economics*, No. 5 (1993): 18-22.

Penning de Vries, F.W.T, 2001. Food security? We are losing ground fast. Pp1-14 in Crop Science: progress and prospects. J.Noesberger, H.H. Geiger and P.C. Struik,eds. CAB International, Wallingford, UK.

Oldeman, L.R., V.W.P. van Engelen, and J. H. M. Pulles. 1990. *The Extent of Human-Induced Soil Degradation*. Annex 5 by L.R. Oldeman, R.T.A. Hakkeling, and W.G. Sombroek, World Map of the Status of Human-Induced Soil Degradation: An Explanatory Note. International Soil Reference and Information Centre, Wageningen, the Netherlands.

Ponting, C., 1991. *Green history of the earth*. Cambridge University Press, Cambridge, UK (350 pp).

Revenga, C.,J. Brunner, N. Henninger, K. Kassem, and R. Payne. 2000. *Pilot analysis of global ecosystems: Freshwater systems*. Washington, DC., USA: World Resources Institute.

Scherr, S.J., and S.Yadav. 1996. Land degradation in the developing world: Implications for food, agriculture, and the environment to 2020. Food, Agriculture, and the Environment Discussion Paper 14. Washington, DC., USA: International Food Policy Research Institute.

Smyth, A.J. and Dumanski, A.J., 1993. An international Framework for Evaluating sustainable land management. *World Soil Resources Report* 72. FAO, Rome.

Stocking, M.A. and N. Murnaghan, 2001. *Field Assement of land degradation*. Earthscan Publication Ltd., London, UK (169 pp).

Wang, Lixian. 1997. Present situation and control strategy of global land degradation. China Soil and Water Conservation No. (1997): 5:8-10.

Valentin, C. 1996. Soil erosion under global change. Pp 317-338 in: *Global Change and Terestrial Ecosystems*. B.H. Walker and W.L. Steffen (Eds). Cambridge University Press, IBPGP Book Series 2.

Wood, S., K. Sebastian, and S.J. Scherr. 2000. *Pilot analysis of global ecostystems: Agroecosystems.* International Food Policy Research Institute, and World Resources Institute. Washington, DC, USA (110 pg).

Zhao, F., F. Hitzhusen and W.S. Chern, 1991. Impact and implications of price policy and land degradation on agricultural growth in developing countries. *Agricultural Economics,* 5, 311-324.