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A Comparative and Transdisciplinary View on Regional Case Studies of Global Environmental Change

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Introduction

Modern Times and Global Change

In former years, let's say at the time of Charlie Chaplin's famous movie 'Modern Times', the various contributions in this volume probably would have been located under a different headline, particularly the notion of 'changing environment' would not have been as dominant. Though many of the aspects reported, like different cultural habits, hardships of poor people trying to meet ends, or more or less ignorant governments failing to provide sufficient support for these people, might also have been elements of such a report. Many of the coping strategies presented in the contributions to this volume are traditionals which have existed for a long time such as the transhumant system of the Massai pastoralism in Tanzania (chapter 6) or the risk-handling system of Huancar pastoralists in Argentina (chapter 9).[1] On the other hand, these traditional risk handling systems are increasingly endangered due to a number of social, political and economical factors. Again, this is nothing new in principle. These kind of changes have occurred throughout history and are also described in a number of the case studies collected here. Examples are the Iloikop wars in Tanzania in the 1840s and 1850s (chapter 6) or the changes, now to be located in the past, due to Apartheid politics in South Africa (chapter 4). So what are the new and outstanding facets and constraints of the current trends in 'coping with changing environments'?

Phenomena of Global Change

The following list of recent developments and trends, taken from the annual reports of the German Scientific Adivsory Council on Global Change (WBGU), might help to give hints to answer the question of what type the novel trends are (WBGU, 1993, 1994, 1997, 1999 a, b, c):

- modification of the physico-chemical composition of the atmosphere and subsequent possible climate change (greenhouse effect);
- soil degradation of all types, e.g., wind and water erosion, compaction, acidification, etc.;
- reduction of natural ecosystems by area and quality, implying significant losses of biodiversity, e.g., deforestation;
- pollution of freshwater resources and coastal zones, e.g., by agricultural and/or industrial activities; and
- massive land-use and land-cover changes throughout the world with global relevance due to changes in the water and nutrient cycles.

These are all aspects of global environmental change (GEC) signifying that humankind has started to transform the face of the earth in an unprecedented way. Though environmental changes have always occurred (just refer to Plato's dialogue *Kritias* written some 2,400 years ago), these trends unveil new properties, both in terms of scale and of irreversibility. Consequently, local coping strategies in face of environmental risks have to be put into the context of these facets of GEC which itself is difficult to be defined in more detail.

Moreover, there are social, political, and in particular economic changes which, with respect to scale and irreversibility, exhibit similar features as the natural trends listed above and which are most often related to or consequence of these environmental changes. Examples include the increase of international agreements, e.g., the growing number of environment related conventions of the United Nations, the so-called globalization of the economy and of communication (world wide web) or the improvement of the medical sciences connected with a rapid and sustained population growth. There are many more of these social trends relating to Global Change (GC). Again, coping strategies are embedded into

this process of Global Change and their effectiveness have to be reflected against them as follows:

- to what extent do coping strategies itself augment Global Change processes? Candidates, for instance, are deforestation processes in the course of slash-and-burn agriculture reported from the Eastern Miombo Highlands (chapter 5), the Tanzanian Maasailand (chapter 6), the Atlantic rainforest of Southeast Brazil (chapter 8) or due to extraction of wood for charcoal production in the Dominican Republic (chapter 10);
- how far are coping strategies already confronted with GC induced environmental and/or institutional risks? Here, most of the contributions are somehow faced with so-called cumulative elements of Global Change (Stern, Young and Druckman, 1992), e.g., soil erosion in almost each of the regions reported on, or, more specifically, decreasing agricultural yields in spite of increasing inputs (chapter 2); aspects of systemic changes, particularly climate change or changes in the world economic structure, can, for example, be found in chapter 5 concerning the cultivation of tobacco as a typical export oriented cash crop; and
- how robust are the commonly adopted coping strategies described in the case studies against further, more drastic global changes? This question provides some background to all of the contributions and is explicitly addressed, e.g., in the introduction of chapter 9.

In this article, we will discuss these questions using the contributions of chapter 2 to 10 and the so-called syndrome concept as a tool for integrating, typifying and condensing case studies to a rather small number of archetypal patterns of Global Change (WBGU, 1993, 1994, 1997, 1999 a, b, c; Schellnhuber, Block, Cassel-Gintz, Kropp, Lammel, Lass, Lienenkamp, Loose, Lüdeke, Moldenhauer, Petschel-Held, Plöchl and Reusswig, 1997; Petschel-Held, Block, Cassel-Gintz, Kropp, Lüdeke, Moldenhauer, Reusswig and Schellnhuber, 1999). We will discuss in the next two sections actor related and environmental aspects of the syndromes and their relation to the regionally specific contributions to this volume. A more formal analysis using modern, qualitative modelling techniques will be performed before turning to the general question on the ‘perspectives of smallholders in the age of Global Change’.

Syndromes as Regional Patterns of Global Change

It is often cited that Global Change is actually a regional or local change in the sense that it is the local action of people which govern the processes of the nature-humanity relationship (Kates, Turner and Clark, 1990). Yet, modern natural science has taught us that there are processes in the earth's atmosphere which transform these local actions into global reactions. Most prominent is the diffusion of greenhouse gases, in particular carbon dioxide, inducing a systemic global change of the atmosphere's energy balance. In the end, there might be a warmer world - at least in terms of global average temperatures. Yet, there is a high regional variability of global warming thus bringing back the effects of climatic change to the people in a variety of ways (Intergovernmental Panel on Climate Change, 1996). As an example, most climate models agree that there will be a pronounced increase in temperature in high latitudes, especially over land, whereas the warming is much more moderate in the tropics. In addition, there is a great regional variation in precipitation changes, both in sign and magnitude.

Besides these systemic changes (Stern, Young and Druckman, 1992), there is a number of so-called cumulative global changes, i.e., these phenomena receive their global relevance by occurring in different regions simultaneously. Examples include loss of biodiversity, soil degradation, population growth, the endangerment of food security, etc. It has to be noted that there are natural, i.e., in the current context environmental as well as social effects. Yet, it would be misleading to analyze these degradation processes in complete isolation from each other and from different regions. An obvious reason for this is that there are still global changes involved, including political as well as economic processes (see above).

Against this background we cannot separate between regional processes and Global Change. This raises the question, how to analyze Global Change without

- simplifying the unique features of local and/or regional situations; this particularly refers to the broad variety of risk handling strategies developed by local actors at different scales; the contributions to the current volume represent a small, but scintillating selection; for others see, e.g., Kasperson, Kasperson and Turner (1995) or Turner, Clark, Kates, Richards, Mathews and Meyer (1990); and

- paying too little attention to the interlinkages and similarities between regions and between processes, and thus to 'good' results from large-scale modelling and assessments; many modelling attempts of Global Change actually focus on these similarities, e.g., by specifying a single mechanism of land-use changes assumed to be valid throughout the world (Zuidema, van den Born, Kreileman and Alcamo, 1994; Alcamo, Kreileman, Krol, Leemans, Bollen, van Minnen, Schaefer, Toet and de Vries, 1998) or throughout a single cultural perspective (Strengers, Elzen and Kösters, 1997).

So far, there are no convincing 'coping strategies' bridging these two extremes of global change research. This is also appreciated in the science and research plan of the International Geosphere-Biosphere and International Human Dimensions Programmes' core project 'Land-Use and Land-Cover Change' (LUCC) (Turner, Skole, Sanderson, Fischer, Fresco and Leemans, 1995, p. 12):[2]

> Modelling the dynamics of land-use and land-cover change has been hindered by large variations of those dynamics in different physical settings. Global aggregate assessments based on simple assumptions miss the target for large sections of the world, while local and regional assessments are too specific to be extrapolated to wider scales.

The approach which we want to present here tries to find a bridge between these two extremes by analyzing regional and local settings which, though geographically different, are similar in terms of

- *actors*, i.e., what social, economic, and political groups are involved in the process of land-use (or global) changes or, more specifically in the focus of the current volume, in the coping strategies in face of changing environments;
- *structures*, i.e., how do actors interact with each other and with their environment and what are the social frameworks for their strategies; and
- *environment*, i.e., what functions of the natural environment are of particular importance in this setting, e.g., is it purely the production function or is their some recreation function involved as, for example, in chapter 6 where tourist hunting activities are mentioned to be relevant for land-use conflicts in the Tanzanian Maasailand.

Though in the present article we mainly focus on the problem of land-use, the approach can be applied more generally, i.e., to Global Change in its entirety. This approach is similar to that taken by the field of pattern recognition known from modern natural sciences (Haken, 1983; Nicolis and Prigogine, 1977). We, therefore, call the similar settings obtained from the analysis *patterns* or *syndromes* of Global Change (see also chapter 1 for an overview of syndromes proposed at the time being).

Syndromes of Global Change: State of Affairs

In order to perform a pattern analysis of globally relevant interactions between nature and humankind, it is not possible to rely on a single best strategy, possibly based on a large set of data. The reason is that the facets of these interactions are so widespread that it is completely unclear which data, both from the natural as well as from the social sciences, are needed to bring about a reasonable and politically usable set of patterns. Also, experience with the most modern methods of pattern recognition has shown that these techniques might tell you something about the topology of the pattern space, i.e., how much, within which geometry and which functional neighborhoods, etc. The interpretation of the results, however, is rather difficult, hiding the actual mechanisms in a black box.

For these reasons, the syndrome approach tries to follow a more semantically oriented path of analysis, and we start from a catalogue of so-called *symptoms of Global Change*.[3] A symptom is already a generalized expression of qualitative and/or quantitative changes in the Earth System which are considered to be relevant for Global Change. 'Generalized' means that regionally specific processes and phenomena can be mapped onto one single symptom. As an example let us consider the symptom 'intensification of agriculture'.

In a number of studies, also from this current volume, the shortening of the period before slashing and burning primary or secondary forests in order to cultivate the area is alluded to as a possible way of preventing a decrease in agricultural yield in face of a degrading natural resource. It is reported, for example, about the Atlantic rainforest in Southeast Brazil (chapter 8) that

> (d)ue to the short period of settlement, no stable rotation system for farming has been established. (…) Sustainable land use either requires inputs of fertilizers (a not very realistic option due to the lack of capital found) or large allotments that allow for the inclusion of adequate fallow periods. Presently,

land managers can still profit from soils and vegetation by slashing and burning the well developed forests.

In other cases, however, intensification might refer to an increased input in terms of implementing irrigation schemes. For example, in the Dominican dry forest (chapter 10) we can observe that, 'due to an irrigation system installed at the beginning of the 1970s in the course of agrarian reform, intensive agriculture is carried out'.

Currently, we are operating with about 80 symptoms from the natural as well as social sciences. The catalogue, however, is continuously modified and updated coinciding with the analysis of an increasing number of case studies. For an actual list of symptoms please refer to the latest annual report of the German Council on Global Change (WBGU, 1999 c).

Yet, Global Change is more than the pure addition or parallel occurrence of symptoms. It is the complex and sometimes highly inertial interaction between the symptoms which constitute the risks people are facing and have to handle. Taking the example of the Atlantic rainforest cited above (chapter 8), we see that there is already an indication for such an interaction, i.e., the 'soil mining character of agriculture' implying on the level of symptoms and their interactions that there is a relation between 'intensification of agriculture' and 'loss of soil fertility' or, even more general, 'soil degradation'.

Borrowing the idea from medicine, a syndrome is now defined as a typical cluster of symptoms and their interrelations. The notion of cluster refers to the concept that different syndromes only weakly interact, i.e., in order to describe, model, or analyze the basic properties of a single syndrome it is not necessary to take into account other syndromes explicitly. Rather they can be 'abstracted' in some weaker form (Petschel-Held, Block, Cassel-Gintz, Kropp, Lüdeke, Moldenhauer, Reusswig and Schellnhuber, 1999).

Case studies like those contained in this volume embody the basic information base used to specify the syndromes. They help to answer questions of what are the interactions between which symptoms. The patterns are formulated in an inductive step, i.e., it is not possible to give a complete set of criteria representing a rationale behind the formulation of a specific set of syndromes. It is therefore necessary to check for the explanatory power of this set and the details in terms of symptoms and interactions. Besides the obvious way of weak testing by discussing it with experts and sustained cross-check with other case studies, the ability to qualitatively reconstruct the time development described in the studies is of

particular importance - for the concept of qualitative trajectories see also Kasperson, Kasperson, Turner, Dow and Meyer (1995). In order to do so in a formally consistent and stringent manner we make use of the concept of qualitative differential equations (Kuipers, 1994). This concept allows all time behaviors which are compatible with a qualitative description of mechanisms like 'A enforces B' or 'C decreases with D' to be determined. If the interactions between symptoms within a single syndrome can at least be qualified in terms like these, we obtain a variety of possible time developments to be compared to those found in the studies.

Table 11.1 Mapping between regional case studies and syndromes

Number of chapter and region of contribution		Syndromes involved
2	Upland area in Nepal	SAHEL
3	Laotian Forest	SAHEL OVEREXPLOITATION ARAL SEA
4	Cape Town, South Africa	SAHEL FAVELA
5	Miombo Highlands, East Africa	SAHEL DUST BOWL OVEREXPLOITATION
6	Tanzanian Maasailand	SAHEL DUST BOWL MASS TOURISM
7	Rural Botswana	SAHEL ASIAN TIGER
8	Atlantic rainforest, Southeast Brazil	SAHEL
9	Andean Mountains, Northern Argentina	SAHEL
10	Dominican Republic, Southwest	SAHEL OVEREXPLOITATION

Syndrome Guesses

Parallel with the more inductive approach to syndrome analysis, we start with a preliminary assignment of the case studies to the syndrome matrix as

presented in Table 11.1. This assignment is based solely on the 'reading experience' of the various contributions and therefore helpful to provide a discussion guideline what is a particular strength of the syndrome concept in terms of its capacity to outline global environmental problems.

It is no surprise that the Sahel Syndrome occurs within all settings. The syndrome exactly deals with the different coping strategies of smallholders within marginal natural landscapes. In particular, the syndrome seeks to specify those strategies within which the network of feedbacks and interrelations finally endanger the livelihood of local people. In many cases, emigration is the only option. A paradigm for this syndrome can be observed in the former homelands of South Africa (chapter 4, p. 113): [4]

> In the rural areas of former Transkei and Ciskei the livelihood was and still is based on subsistence agriculture. However, the subsistence basis has been severely damaged due to food crop cultivation on unsuitable land and due to overgrazing. This resulted in ongoing erosion processes, thus, further destructing the subsistence basis.

In the remaining sections we scrutinize in more detail the Sahel Syndrome. The remainder of this section sheds some light on the other syndromes tabulated above.

Overexploitation Syndrome This syndrome delineates the natural and social processes governing the overexploitation of natural ecosystems in the course of extracting biological resources (WBGU, 1999 c). Important social driving forces are present, in particular massive policy failure (corruption, the inability to enforce rules and regulations for sustainable use of biological resources, lobbyism, etc.). An important feature is the 'stabilization' of policy failure by successful overexploitation. Most prominent examples of the syndrome are sustained deforestation due to industrial logging activities and the boundless depletion of world-wide fisheries. Thus, neither the wood-gathering activities of smallholders nor the conversion of forests due to shifting cultivation are subsumed under the notion of the Overexploitation Syndrome what is the reason why the syndrome is only tabulated for the Laotian forest (chapter 3) and the miombo highlands (chapter 5).

Of particular relevance is the opening of forests by timber extraction activities, often encouraging massive settlement activities in its wake. An example can be found in the study on Laos (chapter 3) stating that 'due to

the construction of weather tracks to transport timber, many formerly inaccessible villages had been connected to the outer world'.

Aral Sea Syndrome A discernible paradigm of this pattern is the ecological catastrophe of the Aral Sea caused by large scale water diversion for irrigation schemes in the now Caucasian steppe. The syndrome describes the ecological and social deterioration as a consequence of large-scale infrastructure projects (WBGU, 1999 a). In terms of global relevance, it is the erection of a total of over 40,000 large dams with a height of more than 30 metres which bestows to this pattern a global relevance (International Commission on Large Dams, 1984, 1988; McCully, 1996). So far, one river system which still exhibits a large untapped potential for hydropower is the Mekong which is one of the subjects dealt with in the case study on Laos (chapter 3). Besides the direct environmental effects of the construction process and the loss of ecosystems due to flooding and change of the physico-chemical regime of the river flow, it is the change of land-use rights and necessary resettlement programs which affect smallholders. On Laos, for example, it is reported (chapter 3) that there is 'evidence of various harmful and project-related effects such as declines in fish catches downstream of Nam-Kading-River, of some villages being impacted by the loss of riverside vegetable gardens and of increasing transport difficulties'.

Favela Syndrome The name *favela* stems from the Portuguese expression for informal settlements hinting to the defining character of the syndrome, i.e., environmental and social deterioration in the course of unregulated urbanization processes. Thus, the aspects discussed in the study on informal settlements in Cape Town (chapter 4) are by definition elements of this syndrome. The mechanisms described in the contribution point out an important property of the syndrome concept in that, as in medicine, one syndrome can vitiate another. Migration as a coping strategy against increasing impoverishment in rural areas can finally lead to environmental crises within settlement areas as such (WBGU, 1999 a).

Dust Bowl Syndrome First, this pattern of Global Change investigates the structures and processes associated with environmental and social quashing due to capital intensive agriculture, often cultivating cash-crops in developing countries, as described for the Tanzanian Maasailand (chapter .6) where, at present, 'about 7,000 ha are cultivated each year for the production of seed-beans, beans, wheat and maize' and where a 'severe consequence is the

inaccessibility of important seasonal and farm-based water ponds' (for the Maasai herders).

Second, however, an important variation of this syndrome concerns plantations for wood production presenting *inter alia* an important source of wood for fire- and flue-cured tobacco production in the miombo highlands of Tanzania and Malawi (chapter 5). Here, the production of tobacco also falls under this syndrome.

Mass Tourism Syndrome The still increasing world-wide numbers of travel activities prompt massive environmental problems from over-proportionally high water withdrawals, sealing of soils for touristic infrastructure to social effects like in Tanzania (chapter 6, p. 169) where

> local Maasai communities hardly benefit from tourism related activities. The villages' shares from 'animal head fees' derived from hunting were not distributed by district authorities.

This exhibits an often found property of syndromes of Global Change, i.e., positively intended activities heading for the improvement of the livelihood of the local communities (e.g., by providing energy, income or water) bring about a number of negative side effects for the environment as well as for marginalized social groups. This might result in improvements of the human well-being and standard of living in spite of serious environmental or ecological degradation (Kasperson, Kasperson, Turner, Dow and Meyer, 1995). At the end, however, the degradation can even outweigh the positive effects and end in a massive deterioration of the living conditions of the local people, leaving them worse off than in the beginning.

Case Study Analyses: Actors and Environment

In general, all the case studies given in chapters 2 to 10 of the volume consider coping strategies of smallholder households in developing countries. This gave rise to the assessment which indicates the dominant role of the Sahel Syndrome. Thus, the question on converging or diverging traits of these strategies will be analyzed in more detail later. With respect to the extent to which other social players are involved and, thus, to what extent external dependencies do exist, the case studies vary. Yet, the main focus is on the role of the state and to a lesser extent on the influence and capacity of national and/or international companies.

Table 11.2 Summarization of the roles of governments as actors impacting upon coping strategies of smallholders

Number of chapter and region of contribution		Role and influence of state or provincial activities with respect to smallholders' coping strategies
2	Upland area in Nepal	Prosecution of illegal timber cutting and/or alcohol production, both representing major (direct or indirect) sources of income.
3	Laotian Forest	Opening the country to foreign investors; road construction providing market access and/or cultivation of paddy rice; prohibition of trade of wood and wildlife products.
4	Cape Town, South Africa	Apartheid politics with social/economic/juridical marginalization of the African majority enforcing use of unsuitable land; provision of area and sometimes infrastructure in informal settlements
5	Miombo Highlands, East Africa	Rural political economy determines *inter alia* the size of the farms and the reliance of the local economy on exporting tobacco.
6	Tanzanian Maasailand	Major impacts on land-use rights; changes of agricultural structure towards cash-crop farming; ineffective social decision-making process by mixing traditional with modern institutions.
7	Rural Botswana	Highly effective governmental drought relief measures; unclear side effects of the measures, e.g., in terms of motivation for sustaining agricultural activities.
8	Atlantic rainforest, Southeast Brazil	Ineffective application of protection rules and control within reservation areas; more or less tolerated squattering and land-use by smallholders, including slash-and-burn techniques on relatively small plots.
9	Andean Mountains, Northern Argentina	State is seen as part of '*gobierno*' by the local people (Huancar), i.e., institutional risk; '*gobierno*' tries to introduce modern specialization instead of the more traditional system of risk aversion by diversification.
10	Dominican Republic, Southwest	State tolerates collection of charcoal by wood-workers; history of failing land reforms and forestry management plans due to corruption; positive examples in the particular study region under the NGO-participation of FEBROBOSUR.

State and Regional Governments

The state as a major actor relevant for the coping strategies of smallholders is evaluated in an ambivalent manner. In Laos, for example, the development of roads and infrastructure as well as the provision of logging licenses has some major direct negative impacts on the environment, i.e., deforestation. Yet, it is observed (chapter 3, p. 89, 92) that

> (t)he opening of forests by logging companies in the 1980s led to a rapid increase of paddy fields. (…) The lack of paddy fields (…) are identified to be the main reasons behind food security.

Table 11.2 summarizes the roles of the state as alluded to in the different studies. First of all, it should be noted that the state plays a significant role in all the regions investigated. Yet, the effects of state interventions vary greatly leading to quite different effects. Thus, though being important, it is not sufficient to investigate the state alone when addressing the three major questions raised above.

Large Scale Companies

In some studies, the role of large, national and/or international companies or landowners is discussed. In general this group can be seen as a further player in the game of diverging interests. Often the state acts in favour of these large companies, e.g., in hope of some tax, license or exchange revenues. Again, the repercussion of this involvement is ambivalent as, e.g., on the one hand these companies act as employers thus providing labor and therefore income for the smallholder reducing their risk by diversification (see below). On the other hand, however, there can be significant marginalization of smallholders due to restriction of land-use rights by large-scale landholders.

The role of large-scale companies is more explicitly addressed in chapter 3 (Laos) and 5 (miombo highlands). For Laos, particular focus is put on the opening up of forests due to logging or hydropower installation activities with direct negative impacts on the environment and indirect effects for emplacing lowland rice paddies, thus providing fairly good income for the local peasants. In contrast, the role of large-scale companies in the miombo highlands is twofold (chapter 5, p. 144):

> Rent-seeking by European farm lobbies had long been prevalent in … parts of Africa such as in Malawi. Aimed at reducing systematically the profitability of small farm cultivation through means such as unequal land distribution and contract farming, more of the smallholders (in Malawi) start now to realize their increased income generation possibilities by entering tobacco market relations after national tobacco monopolies and market access have been deregulated.

In summary, both cases indicate an ambivalence of large company actions as they pave the way for new income options for smallholders. Yet along this way, there had been massive environmental and institutional side-effects.

In the case of Laos, also the important role of international financing institutions such as the Asian Development Bank is addressed. These institutions are of particular relevance for the development of large-scale infrastructure programs like dams or roads. In other words, they are major actors within the Aral Sea Syndrome, as already mentioned above.

Environments

All of the coping strategies discussed in the various contributions depend to a certain extent on the opportunity for agricultural activities and for collection of natural products. There is hardly any capital available to purchase artificial fertilizer or to invest autonomously in irrigation schemes. Therefore, the agricultural yield (and to a similar extent the income from herding activities) strongly depends on the natural conditions, i.e. climate, soil, erosivity, surface water availability, etc. This section will show that all the regions considered can be classified as ‘marginal’. This implies, among others, that any agricultural activity bears a great risk in terms of environmental degradation.

According to the information contained within the different papers, the climatic settings of the regions considered in chapters 2 to 10 range from mountain climates (Nepal, Andean), dryland regions (Tanzania, Malawi, Dominican Republic, Laos), arid to semi-arid conditions (Botswana) to humid or sub-humid climates (Laos, Southeast Brazil, Eastern Cape Province of South Africa).

There is, however, no general stringent information on the natural conditions for agriculture in the different regions. We therefore rely on a global assessment of marginality for agricultural land-use which is based on global data-sets of climate (temperature, precipitation, solar radiation, inter-

annual variability of the growing season), soil properties (water retention, fertility), orography, and surface water availability (Cassel-Gintz, Lüdeke, Petschel-Held, Reusswig, Plöchl, Lammel and Schellnhuber, 1997; Lüdeke, Moldenhauer and Petschel-Held, 1999). The analysis is set-up as an expert system, i.e., the evaluation of marginality mimicks an expert's argument using basic logical arguments like 'if soil fertility is low then growth conditions are bad'. The result of the analysis between 0 (no marginality) and 1 (highly marginal) can be depicted as a world map of agricultural marginality. It represents the natural component of the *disposition* for the Sahel Syndrome and indicates those regions whose natural prerequisites put a high risk on agricultural activity. A world map where regions particularly marginal are depicted dark is provided in Figure 11.1, having a spatial resolution of 0.5° x 0.5° which is 55 km x 55 km around the equator.

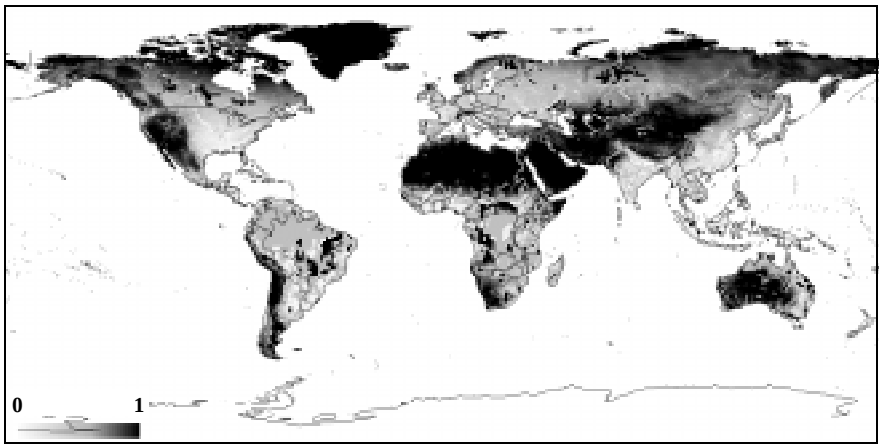


Figure 11.1 Global assessment of marginality with respect to agricultural activity

We have extracted the marginality values for the different study regions of this volume. The results, as presented in Table 11.3, suggest that all study regions show some degree of marginality. We also have included the result from the sensitivity analysis with respect to climate (Lüdeke, Moldenhauer and Petschel-Held, 1999).[5] This measures whether climate change will change the marginality in the respective region. As can be seen, the marginality in most regions depicts some degree of sensitivity which can augment the endangerment of the regional ecosystem by any

agricultural or gathering activity. It has to be noted, however, that this measure only allows to speak about a chance of improvement or worsening and not about the actual direction. The reason is that we do not specify a certain direction of climate change due to the large degree of uncertainty in the model results.

It can be seen that the two mountainous regions, i.e., central Nepal and Huancar District in the Andes of Argentina have the highest marginality values of all study areas. This is mainly due to the rather cold climate which limits natural growth. This kind of limitation is reflected in the preference of herding activities as *one* major element of local coping strategies (see below). Yet, the sensitivity assessment indicates in both regions a slight chance for improvement, as the temperature limitation might be weakened due to global warming.

Table 11.3 Marginality M ∈ [0,1] of the study regions as obtained from the global assessment of agricultural marginality

Number of chapter and region of contribution	Value of marginality	Sensitivity against climate change
2 Upland area in Nepal	0.9 - 1.0	low
3 Laotian Forest	0.3 - 0.5	medium
4 Cape Town, South Africa	0.2 - 0.8*	low
5 Miombo Highlands, East Africa	0.3 - 0.85	medium - high
6 Tanzanian Maasailand	0.4	high
7 Rural Botswana	0.5 - 1.0	low - high
8 Atlantic rainforest, Southeast Brazil	0.05 - 0.25	none
9 Andean Mountains, N-Argentina	0.9	low
10 Dominican Republic, Southwest	0.2 - 1.0	low - medium

* Indicator for regions from which people in the informal settlements of Cape Town originally came from (Eastern Cape Province).

Some parts of the rural areas of Botswana have also quite high values of marginality. Here, water is the limiting factor for agriculture except for the Northwest where surface water of the Okawango reduces marginality. Care has to be taken, however, as the assessment does only include environmental damages due to agriculture. Therefore, damages due to large scale water diversion systems as sometimes suggested for the Okawango are not included. The environmental threats of such projects are investigated within the analysis of the Aral Sea Syndrome. Concerning sensitivity, it can be stated that for Botswana it shows a high spatial variability the pattern of which, however, does not coincide with the spatial pattern of current marginality. Therefore, it can be expected that there are winners and losers of climate change in this country.

Intermediate values of marginality are found for the three study regions in Africa (i.e., Eastern Cape Province of South Africa, Malawi and Tanzania), for Laos and for the Dominican Republic. Here, it is a mixture of climatic and soil properties which determine their values. Though there is a risk of soil degradation, it equally exists a fairly good chance for sustainable agriculture with little effort. This can, for example, be seen in the Laotian case of lowland paddy rice fields (chapter 3, p. 90) as

> the risks of soil erosion are reduced in the case of lowland rice cultivation. Another advantage of lowland rice cultivation is the long-term conservation of soil fertility. In Sangthong District, buffaloes and cattle graze on paddy grounds after the harvest, at the same time maturing the paddy fields.

The sensitivity analysis shows varying results for these regions mainly within an medium range. Thus, there is danger that in these regions a significant increase of marginality might occur, thus, sometimes augmenting the local dynamics of soil degradation and resource depletion. If all the study regions collected in the volume are to be compared, these regions can be considered as the most endangered ones in face of a changing world climate.

Having a closer look at the case studies, however, reveals an important deficiency of global analyses. As the assessments already aggregate, e.g., for soil fertility a spatial resolution of 1° x 1° degree is used based on the soil map of FAO (Zobler, 1986), any displacement processes to allotments of low productivity within a region of fairly good conditions is not sufficiently taken into account. Description of such kind

of processes can be found, e.g., for the Eastern Cape Province (South Africa) or for the Atlantic rainforest (in Southeast Brazil).

The lowest marginality values can be found in the Atlantic rainforest in Southeast Brazil expressing rather favourable conditions except for low soil fertility (see above). This is also the reason why sensitivity in this region vanishes.

In summary, it could be stated that in all of the areas under study the medium to high degrees of ecological risks, together with the highly ambivalent role of state and business interventions, result in a similar pattern of ecosystem endangerment that is largely shaped by institutional factors. This situation requires highly adapted social strategies. A comparison and integration of the different strategies reported in this volume is given in the next section.

Comparing Smallholders' Coping Strategies

Here and in the following sections we want to talk about strategy which for itself is a dynamic notion. In principle, a strategy can be interpreted as a skill to aid survival in dangerous situation. The military usage of the notion of strategy is connected with a set of stratagem, or in other words a tool box of options which are used in the course of time to achieve a certain target. Transferred to the problem of coping strategies in changing environments, we, first, have to identify the toolbox of options that smallholders are using in different regions.

A detailed study of the contributions collected in this and other volumes (Little and Horowitz, 1987; Blaikie and Brookfield, 1987) reveal that, in principle, there are three main options for supporting livelihood:

- agricultural activity, i.e., growing crops or herding animals; the products can either be used for subsistence (LAS) or sold or bartered on markets (LAM);
- gathering or hunting pursuits, e.g., wood or non-wood forest products, game, which again might either be used within the own household (GS), sold directly, or sold after some value-adding production process (GM); and
- wage labor, often related to agricultural activities (LW), e.g., on large estates or holiday farms as mentioned in the study on the Atlantic rainforest in Southeast Brazil.

Some of the studies in this volume go beyond this set of options. In chapter 1, for example, it is noted that ‘another coping mechanism being forced upon the people is to consume less than the minimum requirement needed for an active and healthy life’. And, similarly, in chapter 4 the question is raised whether rural-urban migration can be viewed as a coping strategy. In the following, we want to concentrate on the supporting options tabulated above. We refer to this set of options simply by the notion of ‘option-box’.

The question we would like to address is whether the different strategies of all the smallholders reported in the various contributions obey a general rule or set of rules. This general rule would represent a major element of the mechanism of the Sahel Syndrome, particularly with respect to its social component. The specific strategy within a region would then be the result of combining this general rule with the situation and environment of the local people. Some aspects of this determining situation are actually outcomes of the local interaction between humans and nature, itself determined by previous decisions and actions. Thus, there is a significant degree of feedback in the system. This implies that the metamorphosis of the coping strategies to a certain extent are self-determined. We will discuss the implications of this feedback net and the degree of self-determinism by using a qualitative model of the smallholders activities in the next section.

Within this approach, major external elements play an important role, e.g., the influence of the state, on the one hand, and the environmental conditions on the other hand (with both alluded to in the previous section). For the moment, we want to assume that the environmental conditions as assessed and mapped in Figure 11.1 remain constant. Therefore, we can assume that the change in the natural conditions for agriculture such as soil fertility are solely governed by the local environmental effects in course of agricultural and/or gathering activities. Basically, this is one of the major feedback mechanisms within the study regions. As all the environments have to be considered as vulnerable, inappropriate strategies of resource use will finally lead to massive degradation and thus losses of the income base. Again, we refer to the modelling section below for the various implications.

The governmental ventures, as listed in Table 11.2, will be taken into account exogeneously when checking the explanatory power of the basic rules of the Sahel Syndrome to be delineated below. Before doing that, we first analyze the case studies with respect to the basic set of options listed above.

Most of the contributions in the volume report on the metamorphosis of coping strategies within the last years (even up to decades) and not on current strategies alone. These metamorphoses are summarized in Table 11.4. The attempt was made to depict not only the options actually used in the specific regions but also their current direction of change (to the extent it is known).[6] An increase in activity is indicated by an upward arrow (↑), a decrease by the corresponding downward sign (↓), and no change by a small circle (°). If no information on the direction of change is available, the corresponding box is simply checked by an x. The abbreviations used for the different labor activities are those introduced in the listing of the option-box above.

It is obvious that by forcing the different strategies into the rather simple scheme of five basic options, other basic social elements of the strategies are ignored. The scheme contains no information, e.g., on changes due to individualization in course economic development, as reported for rural Botswana (chapter 7, p. 181-2) since

> (d)rought was looked upon as a group problem which was to be solved by concensus within the group. Today, given the quickly modernizing Botswana society (…) drought is often perceived as an individual problem, with strategies taken up by individuals as outcomes of individually satisfying mediation.

In analogy to Stern, Young and Druckman (1992), we might therefore interpret the strategies as designated by the five basic elements of the options-box as 'proximate' strategies in contrast to a detailed sociological decomposition.

In addition, Table 11.4 also contains information on whether there is massive environmental degradation going on in the respective region (column ED) which is related to activities within people's livelihood. The scheme is analogous to the one for coping strategies. A question mark is put when no information is available. In summary, the result of the case study analysis as presented in the table represents a first step in the generalization scheme discussed above, i.e., general variables able to subsume details of the case studies are formulated and values assigned.

First of all, it is observed that the chapters 2 to 10 cover a broad range of different coping strategies, in particular when looking on current changes in composition. Basically, all strategies can be typified as *risk management by diversification* which fits well into traditional theoretical frameworks and is explicitly addressed in chapter 4 making the point that the 'more diversified the portfolio of strategies is a person or group can dispose of to

cope with vulnerability, the better are the chances to keep up the *status quo* or even enhance the respective living conditions'.

Table 11.4 Generalized proximate coping strategies and environmental degradation (ED)

Number of chapter and region of contribution	Coping strategies [a]					
	LAS	LAM	GS	GM	LW	ED [g]
2 Upland area in Nepal	↓			x	↑	↑
3 Laotian Forest [b]	(↑,↓)	(↓,↑)	x	x		↑
4 Cape Town, South Africa [c]	↑				↑	↑
5 Eastern Miombo Highlands [d]	↓	↑		↑		↑
6 Tanzanian Maasailand [e]	(-,↓)	(↑,-)		x		(↑,°)
7 Rural Botswana	↓	↓			↑	x
8 Atlantic rainforest [a]	(↑,↓)				(0,↑)	↑
9 Huancar, Andean Mountains	x	x	x	x	x	
10 Dominican Republic [f]	x		x	(↑,°)	x	(↑,°)

[a] See text (p. 272) for an explanation of the abbreviations used.
[b] There is some difference in the allocation between LAS and LAM between the two major study regions of the contributions. Therefore two entries are made to indicate the differences.
[c] See Table 11.3.
[d] Here wood is not sold directly but used in the tobacco curing process.
[e] If there is a difference between the activities of farmers and of herders indicated in the text, the first entry relates to the new farmers and the second to traditional herders. The entry '-' means an absence of the respective pursuit.
[f] The second entries concern the values after implementing the *Proyecto Bosque Seco* in some dry forest communities.
[g] ED = environmental degradation.

The effect of non-available diversity can be seen, e.g., in the contribution on South Africa in that the almost purely subsistence based livelihood finally leads to migration as the only ‘way out’ from the degradation-impoverishment-spiral - what is a paradigmatic course of the Sahel Syndrome.

It also can be seen that from almost all regions a severe environmental degradation is reported. In particular this refers to high levels of different types of soil degradation, e.g. nutrient depletion or erosion.

We can now specify our basic question in more detail as follows. Is there a common set of rules which implies that the nine strategies shown in Table 11.4 will ensure, at least to some extent, the successful coping (or survival, even) of smallholders in spite of a degrading environment and the impact of governmental actors?

A Qualitative Model of Smallholders’ Coping Strategies

In order to answer this question a qualitative modelling approach is applied in this section. It will be shown that this is possible to some degree by implementing a relatively simple cause-effect-net which connects several aggregated variables (Figure 11.2). This net is a specified part of the more general Sahel Syndrome which has been shown to cover the most important viewpoints of the case studies presented here. Taking the flow diagram of Figure 11.2, it becomes impossible to deduce the possible developments relying only on plausibility. That is the reason why we use the concept of qualitative differential equations (QDE). This methodology allows us to deduce *all* qualitative time developments of the considered variables which are in accordance with the cause effect net.

The method does not require further specification of the qualitative relations (e.g., by quantification) and, thus, allows a more direct mapping and evaluation of ‘word-models’ to be made. It may, therefore, fill the gap between traditional mathematical modelling and plausible reasoning, keeping (in part) both the exactness and clear distinction between assumptions and deduced conclusions of the former and the generality and the necessarily wide concepts of the latter.

The QDE concept formalizes the connection between cause-effect assumptions and the (endogenous) time development in form of qualitative trajectories. We, thus, can be more specific in our basic question to the following. Does the QDE-based qualitative modelling of the simple

network of interrelations in Figure 11.2 reconstruct the qualitative observations and is, thus, 'non-falsified'.

Livelihoods of Smallholders from a Systemic Point of View

As a first step in classifying the livelihood resources of smallholders in developing countries (with respect to cybernetic aspects), we distinguish the activities which (a) directly rely on the use and management of natural resources and (b) activities which do not imply disposal or direct use of natural resources. In category (a) we find the different forms of farming (sedentary, slash and burn, livestock, etc.) including gathering (e.g., fuelwood) and hunting, while category (b) includes gaining income through wage employment in villages (e.g., in agriculture) and in town (e.g., in the service sector).

Now, there is an inherent ambivalence based in the structure of the activities of category (a) which can be elucidated by introducing three aggregated terms:

- QR, signifying the quality and quantity of the natural resource base important for smallholder production (e.g., soil for agriculture, productivity of grasslands for livestock or of woody vegetation for gathering fuelwood or exploitation of timber);
- LA, signifying the investment of labor into the activity (e.g., ploughing, weeding, gathering); this means that the important sub-allocation into the different aspects of agricultural work, especially the distinction between resource quality preservation measures and activities mainly aimed at short-term oriented exploitation is aggregated in one single term; compared to the more detailed option-box described above, LA subsumes the categories LAS, LAM, GS and GM; and
- Y, signifying the physical output of the activity (crops, milk, fuelwood, etc.).

Obviously, the yield (Y) depends both on the quality of the resource (QR) and the investment of labor (LA). The specific form of this relation will vary largely over the different agricultural systems, including climate and soil conditions, techniques applied, etc. The properties which are common, however, are as follows. First, without any labor (LA = 0) or with vanishing quality (QR = 0; e.g. agriculture on rocks), no yield (Y= 0) will

be achieved. Second, increasing QR or LA while keeping the other value constant will increase Y. Exactly these two (very weak) properties define the 'qualitative product' in the QDE-formalism.

Unfortunately, the input of labor is not only the condition for production of yield but is at the same time often the cause for the degradation of the natural resource base. Therefore, the influence of LA on the *change* in QR has to be considered. Assuming prevailing agricultural techniques, the resource quality in general decreases faster, if the intensity increases. Conversely, at relatively low intensity even a *recovery* of the natural resource base may occur (e.g., the growth of secondary forests during fallow periods). The intensity which ensures the use of the natural resource without depletion will again depend on several natural and management-dependent factors which are difficult to determine. In accordance with the QDE concept we only assume that such a specific value of LA exists. We call this value *ms* (maximum sustainable intensity). One has to keep in mind that this value depends on the specific division of LA in quality preserving and short-term exploiting measures.

In order to illustrate the functioning of the QDE-formalism let us assume that the simple system described above, i.e., constituted by QR, Y and LA, faces an exogenous determined continuous increase in LA. In this case the formalism deduces three different qualitative time developments ('behaviors').

In Figure 11.3, the possible solutions are shown in detail for QR, Y and LA. Each plot depicts the time behavior of one variable with time on the abscissa and the qualitative value on the ordinate. Thus, the *labor input* in trajectory 1 stays above the value of *ms* for all times. In addition, the arrows indicate the direction of change (see above), i.e., in this example it is also increasing over all times.

The result mainly depends on the starting value for LA. If one starts with an input greater than *ms*, QR is reduced throughout at all times (trajectory 1). Due to the increase of LA and the simultaneous decrease of QR, the direction of Y is undetermined (double-arrows) until the resource is exhausted (QR = 0 at T1) which enforces vanishing yield. Starting with LA = *ms* yields a similar result while in the case of an initial value less than *ms*, at first a recovery of the resource (increase of QR) can be observed resulting in an increasing yield over the first time interval. While LA passes the *ms*-landmark, the recovering trend of QR is reverted, which leads finally to a similar situation as for trajectory 1.

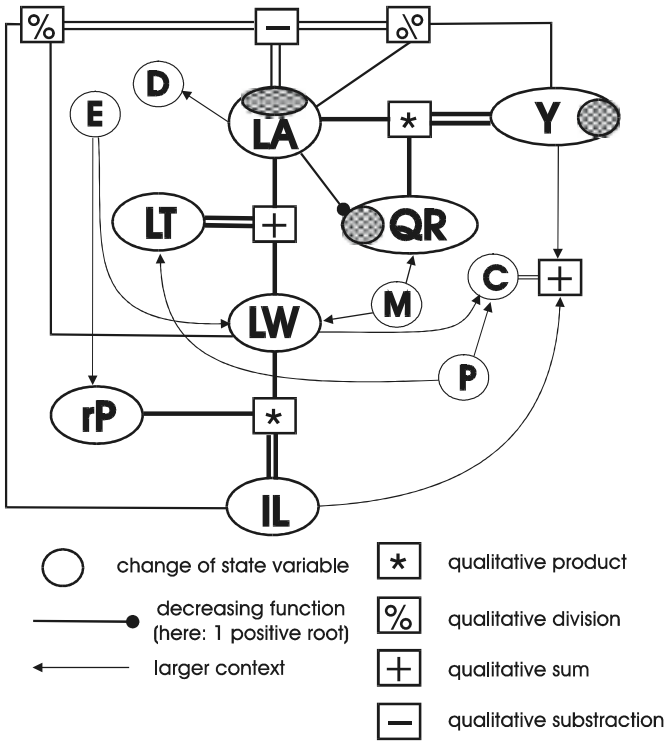


Figure 11.2 Qualitative model for typifying and integration of smallholder's coping strategies into a single set of rules

Variables explicitly included in the qualitative model: LT: total amount of labor; LA: labor investment in agricultural activities; LW: labor investment in wage sector; QR: quality (and quantity) of natural resources; Y: physical yield from agricultural sector; rP: price for agricultural produce relative to present wages; IL: income from wage labor; C: consumption per capita. *Important external variables*: M: socio-economic marginalization of smallholders; P: population; E: national economy; D: Degradation of nature without direct feedback on the resource base.

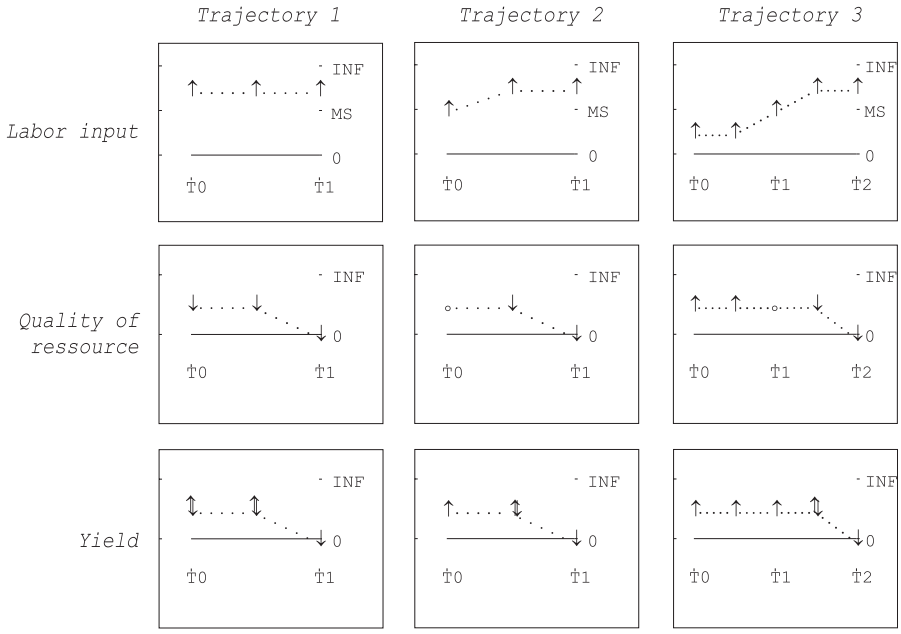


Figure 11.3 All different solutions of the qualitative model if no wage labor is present and labor input into agriculture is continuously increased

Allocation of Labor

The next step in the extension of the simple smallholder model is to introduce the possible division of the total labor potential (LT) into agricultural (LA) and wage labor (LW) activities which, on the other hand, means that LW and LA sum up to LT. The resulting total income (C) consists of the labor income and the income from the agricultural sector (direct consumption, barter, sold at the market). The averaged price relations between the agricultural and the wage labor sector (rP) can be described by the wage per labor unit relative to the mean price of agricultural produce.

In the next step, we include in the model a hypothesized rule of how labor is allocated in the smallholder economy. In an economistic approach, the optimal allocation would be considered assuming the full knowledge of the production system or expressing the uncertainties by probability

distributions, and finally optimizing an appropriate goal function, e.g., the integral of the discounted yield over a given time period. It is disputable whether the rules of traditional production systems in their traditional environments approximate such an optimal resource management. Yet, it seems reasonable to assume that under the present unused conditions, smallholders are dealing with a new type of option-box. A relatively widespread criterion for the continuous evaluation of labor allocation decisions is the comparison of the mean outcome per labor input. If it turns out from the comparison that the smallholder is better off in shifting the allocation, it is assumed that he will do so. In the case of our aggregated allocation scheme here, this means to compare the outcome per labor unit of agricultural and the wage labor and reallocate the total available labor in the direction of the more labor efficient activity.

The qualitative model thus developed is a specific part of the overall Sahel Syndrome network of interrelationships where we summarized the complicated dynamics of the natural resource base by only one aggregated trend combining quality and quantity of the natural resource. In Figure 11.2, additional interactions are shown (thin lines) which are relevant for the syndrome but can be interpreted as external in the context of this study. First, some management induced damage of nature (D) which does not directly feed back on the smallholder production system (e.g., loss of biodiversity) has to be considered. Further, we would have to take into account aspects of marginalization (M) leading to restricted access to productive natural resources or wage labor. Next, the influence of population (P) as a source for labor, on the one hand, and divisor for income, on the other hand, should be taken into consideration. Finally, the national and international economic development (E) as determining prices and availability of wage labor has to be reckoned with.

Within the analytic framework of qualitative differential equations we might consider these variables as hidden determinants for the more specific form of those qualitative relations used in the model. For example, all else being equal, population increase will lead to a decrease in consumption. Yet independent of the actual value of P, at present assumed to be constant, any increase of yield Y increases consumption.

Are Important Features of the Case Studies Reproduced?

In Figure 11.4, the structure of all developments which are in accordance with this qualitative model of smallholder labor allocation, income and

resource degradation outlined above is displayed. Each marker represents one (numbered) specific state of the system. A state is given by the *qualitative value* and the *direction of change* for each of the variables. The state of the system evolves in time along the branches of the tree. For example, state 1454 has three possible successor states, i.e., 1455, 1446 and 1457. Which of these states in the dynamic development actually follows on state 1454 is not determined by the current formulation of the qualitative net cause-effect in Figure 11.2. Therefore, all possible successor states have to be taken into account. Such ambiguities are the price to pay for the purely qualitative nature of the model.

Specifying the initial condition by requiring that none of the values should be zero or infinity, a total of nine consistent initial states is possible. These states are the ones represented by the first symbols at the left hand side of the tree. The symbols on the right end of each of the nineteen behaviors possible in total indicates whether (a) a jump to another state in the tree eventuates to continue the system development (short diagonal line, the number of the target state is indicated after equal sign), (b) a jump to a previous state on the own trajectory occurs (small circle), or (c) an equilibrium (dot) is achieved.

The first observation is that the dynamics of the system is dominated by cyclical behavior, i.e., almost all branches end with a jump to another state. Only two ends of branches are indicated as equilibria with one of them (no. 1593) being unstable.

The prevailing cyclical behavior is mainly due to the reactive allocation strategy of the smallholder, i.e., when labor productivity of agriculture declines due to decreasing resource quality, the labor input into this sector is reduced, if wage labor is relatively more attractive. The reduction of agricultural activity results after some time in a recovery of the resource. This makes the agricultural activity attractive again which can induce reallocation of labor into the agricultural sector. The frequency of the oscillatory behavior depends on the characteristic time of resource deterioration and recovery which may vary between years and decades. Qualitative modeling cannot resolve the time scale problem as the time points in the solutions of QDEs are just ordered symbols, i.e., time *point* T4 is later than T3 which itself is later than the *interval* (T2,T3). Time points T1, T2, etc. are not divided into equal time slices, but defined by ‘events’, i.e., characteristic changes in the behavior of at least one system variable. In this sense the event ‘resource quality stops decreasing’ determines one time point.

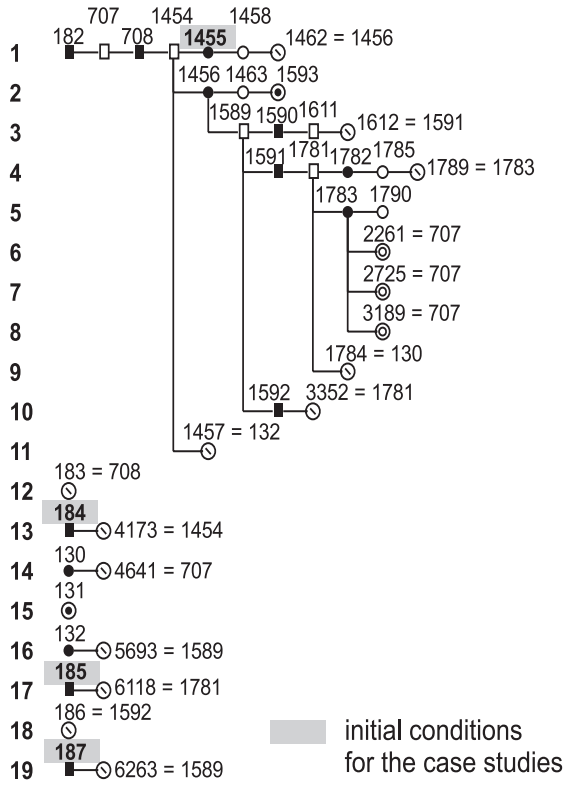
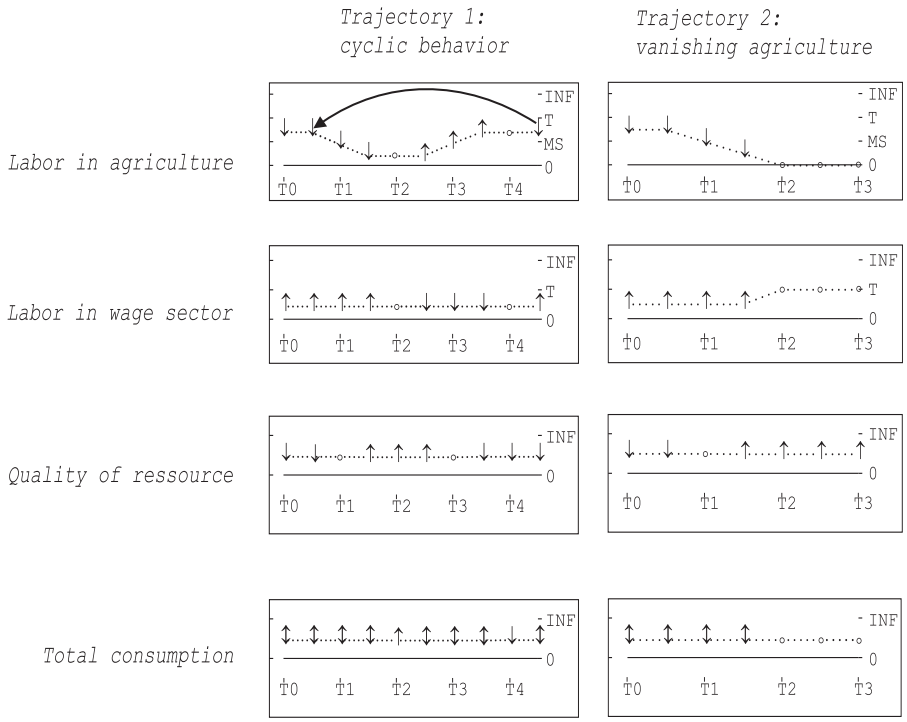


Figure 11.4 Complete behavior tree of the smallholder model

In Figure 11.5, two possible behaviors of the system ('qualitative trajectories') are shown in detail. The state variables displayed are the labor allocated to agriculture (LA), to wage labor (LW), the quality of the natural resource (QR), and the total consumption (CT). Both trajectories start with state 187 (line 19 of Figure 11.4).

In the following sub-section, we discuss how the strategies described in the contributions are reconstructed by the model in form of different branches of the tree.[7] The results as discussed below are summarized in Table 11.5 which also includes an entry describing the future prospects of the regions according to the model output.



Trajectory 1: 187,6263=1589,1592,3352=1781,1784=130,4641=707,7081,1454, 1457=132, 5693=1589 → cycle.
Trajectory 2: 187,6263=1589,1592,3352=1781,1783,1790.

Figure 11.5 Two typical behaviors starting from an initial condition compatible with the case study situation in Nepal

Nepal The initial state 187 characterized by declining quality, decreasing labor in agriculture and increasing activities in off-farm labor, can be assigned to the case study on Nepal (chapter 2). The mixed strategy observed among upland farmers there is obviously consistent with the applied qualitative model. It should be noted that this is not as minor as one might suppose since there are only nine consistent initial states and, thus, the fact that one of them coincides with the study of Nepal is remarkable.

Inspection of all the trajectories starting from this initial condition shows that a constant coexistence between wage labor and agricultural labor is *not* possible. Due to the internal dynamics of the agricultural production system, e.g., sustained soil degradation, different forms of oscillations occur. Trajectory 1 in Figure 11.5 shows one such oscillation

without intermediate complete allocations of labor into one sector, i.e., it preserves the mixed strategy at all times. It further avoids the temporal, though reversible complete loss of the resource base. This seems to be a positive prospect and should be supported by appropriate policy measures. It means counteracting the total withdrawal from wage labor, keeping wage labor attractive and avoiding incentives to extent agricultural activities. Yet, the development of the total income remains unclear. This, in addition, implies that the time course is very sensitive to the exact form of the interrelations, except that there is no dramatic decline at all.

Table 11.5 Overview of present states in the case studies (numbers of chapters) and of near term prospects (i.e., possible successor states)*

Case study	Present state in the model				possible successors				
number	No.	LA	LW	QR	No.	LA	LW	QR	criticality
(2), (7)	187	>ms,↓	↑	↓	1590	>ms,↓	↑	0	high
					1591	ms, ↓	↑	0	medium
					1592	ms,↓	↑	◦	low
(10),(4),(5)	184	>ms,↑	↓	↓	1455/6	(T,°)	0	↓	high
					1457	>ms,°	°	↓	medium
(8; Bela Vista)	1455	(T,°)	(0,°)	↓	1593	>ms,°	0	0	high
					1589	>ms,↓	↑	↓	medium
(8; Dois Irmãos)	185	<ms,↓	↑	↑	1782/3	0,°	T,°	↑	low
					1784	<ms,°	<T,°	↑	low
(3, Ban Kouay)	Traj 1, t=T0	>ms,↑	0	↓	Traj 1, t∈(T0,T1)	>ms,↑	0	0	high
(3, Ban Taohai)	Traj 2, t=T0	ms,↑	0	◦	Traj 2, t∈(T0,T1)	>ms,↑	0	↓	medium
	Traj 3, t=T0	<ms,↑	0	↑	Traj 3, t∈(T0,T1)	ms,↑	0	◦	low

* The first four cases refer to the behavior tree of the complete allocation model as shown in Figure 11.4. The last two cases, one of which is not unique, are related to the simple model as given in Figure 11.3.

Trajectory 2 in the figure is the only possible time behavior which exhibits a stable total consumption, i.e., this stability is possible only by the total retreat from agriculture. This holds true under the assumption of relatively stable wages, which, of course, has not necessarily to be the case.

Eastern Cape Province (South Africa) Before migrating to Cape Town, the situation of households in rural areas was characterized by decreasing wage labor due to a discriminating Apartheid system (chapter 4). Accordingly, the activities in subsistence agriculture have been increased, accompanied by a decline in natural resources. This, again, is represented by the initial state 184. Along the trajectory following the states 1454, 1456, 1463 and 1539 the natural resource base is completely diminished at the end. This corresponds to vanishing consumption and, thus, emigration (not modeled here) is the only way out. This actually has happened in South Africa.

Eastern Miombo Highlands Here, it is reported (chapter 5) that in the case of Malawi 'farm operations imply any transition from subsistence production with occasional tobacco market relation and wage labour to petty and extended (tobacco) commodity production'.

This has been translated to the corresponding entry in Table 11.4 and corresponds to state 184. Here, also the 'soil mining' character of tobacco has been used to indicate a decreasing quality of soils - see Table 11.5. The remark given at the end of the contribution, i.e., that if soil mining continues as it is the production potentials of agriculture and the natural environments will be undermined is represented by the trajectory ending in the final state 1593.

Rural Botswana The remarkable governmental drought relief measures in Botswana (chapter 7) can be mapped onto a supported increasing wage labor, decreases of both agricultural activities and resource quality. Again, initial state 187 describes this in terms of the qualitative model. Thus a similar argument holds as given above for Nepal. Yet, the prospects are better here in so far as the governmental measures and the overall better economic situation of Botswana provides a good chance for a promising future.

Dominican Republic The study about the charcoal burners in the Dominican Republic (chapter 10) characterizes their present situation by decreasing wage labor over the last few years. This is reported as a result of a switch from cattle to crop farming which is less labor intensive. Furthermore, the wood-workers have increased their collection activities, here expressed by LA and a documented decline in the natural resource base. This situation is reconstructed by the initial state 184 (line 13 of Figure 11.4) followed by state no.1454 (first line in Fig. 11.4). The GTZ-

project *Proyecto Bosque Seco* is reported to largely relief the pressure on natural resources. The project wants to introduce more sustainable methods of forest management, e.g., the use of dead instead of 'green' wood. Within our qualitative model this *exogenous* project can be expressed by increasing the labor threshold for non-sustainable resource use *ms*, i.e., a constant labor input which is non-sustainable (LA > *ms*) before the implementation of the new management strategy may turn into a sustainable use (LA<*ms*). Such an externally induced change in *ms* transforms to a 'jump' in the behavior tree (Petschel-Held, Block, Cassel-Gintz, Kropp, Lüdeke, Moldenhauer, Reusswig and Schellnhuber, 1999). The case of the *Proyecto Bosque Seco* corresponds to a 'jump' from state 1454 to state 707 which is characterized by LA less than *ms*, an increasing QR and all other variables equalling those in state 1454.

This 'jump' allows one to evaluate the further development by application of the behavior tree. It shows that the system will inevitably run once more into the undesirable state 1454 because there are no bifurcations in between. So the measure improves the situation but after some time the internal dynamics of the system will reach the old non-sustainable development stage. This corresponds to the situation that due to the positive income effect induced by the project, more and more woodworkers would like to join. In the current model it is assumed that the total available labor is *above* the maximal sustainable yield *ms*, thus, if finally all woodworkers take part the work will be unsustainable. Therefore, we can say that the measure can be unremitting success only if total labor is less than *ms*.

Atlantic rainforest, Southeast Brazil Here, together with the contribution on Laos, two distinct dynamic states are identified according to the two major villages investigated in each study.

In the village of Bela Vista described in the study on Brazil (chapter 8), a constant and high input into agriculture was accompanied by a decreasing resource base and decreasing income. This corresponds to state 1455 which in Figure 11.4 was not explicitly indicated as an initial state. For the second village, Dois Irmãos, decreasing LA, increasing LW and increasing resource quality was found. This represents a positive development which is represented by the initial state 185. By tracing the further development of Bela Vista (1455) the undesirable situation remains until state 1456 is reached. Here a bifurcation occurs which will lead the village either into the disastrous situation of totally exhausting natural resources accompanied by a total decline in income (state 1593) or via 1598, 1592, 3352 to the present

state of Dois Irmãos. Conclusively, if at the bifurcation point sufficient wage labor is provided, there is a real chance that Bela Vista can follow the positive path of Dois Irmãos.

Laos In this study (chapter 3), wage labor is generally not a significant alternative to agriculture. Therefore, we have to switch from the labor allocation model which was the basis for the discussions so far, to the results of the simple agricultural model described at the beginning of this section.

Ban Kouay, the first of the villages studied in Sangthong District, shows increasing agricultural activity related *inter alia* to population growth accompanied by decreasing resource quality. This is identified with the initial state (i.e. at time T0) of trajectory 1 - see Figure 11.3. As can be seen, the development of yield (Y) is underdetermined due to the counteracting effects of increasing input and decreasing resource quality. However, the trajectory terminates with totally depleted natural resources and vanishing yield.

In Ban Taohai, on the other hand, increasing agricultural activity is associated with non-decreasing (i.e., constant or increasing) resource quality which can be approximated by the initial state of trajectory 2 or 3, both leading to an increase in yield. But even this positive development in yield is endangered under a steady increase in LA. After LA has passed the critical *ms*-value, the yield increase will return to its former value with a certain time delay, because the instant decrease of QR is masked by the LA increase for some time. Therefore, evaluation of the agricultural system only on the basis of yield development may drive the system in dangerous and almost irreversible states.

Conclusions

The current article has striven to integrate the various contributions contained in this volume. It has been shown that due to the high levels of interlinkages between regions (both due to social and natural processes) it is necessary to relate local developments to Global Change. To this end, it was suggested to perform a pattern analysis of Global Change in order to bridge the gap between specific local aspects and global processes. The integration and comparison of the different

contributions has been carried out in the custom of this *pattern identification process.*

It has been shown that all the contributions contain some elements of the Sahel Syndrome representing a major pattern of Global Change. All regions exhibit a serious degree of marginality of agricultural land-use. In many regions marginality is sensitive to climate change.

Using a qualitative modelling approach, it was possible to show that, in spite of dissimilarities in the role of the state, large scale companies or international actors, the coping strategies of smallholders, in principle, obey the same set of basic rules. The centerpiece of this *coping rule* is a rational decision between wage labor and agricultural (farming, herding, collecting) activities. Furthermore, it shows that the diversification of labor allocation between these options is in favor of a sustained livelihood within the region. Otherwise emigration might appear as the only way out of the degradation-impoverishment-spiral.

Coming back to the three basic questions which relate local coping strategies with Global Change (and which have been raised in the introduction), the following conclusions can be drawn.

First, and as it has been supposed in the beginning, the regional settings described in the volume contribute to Global Change through their high levels of soil degradation. Globally, this is important as it represents a significant impact on the global food security system. Locally, there is any reason to assume that in some of the regions smallholders cut the ground under their own feet. Exceptions with good prospects of escaping from increasing soil degradation can be found in Botswana and the Dominican Republic. We can assess the overall criticality by using Table 11.5. We recognize that, independent of the actual path taken, a significant risk exists for the Southwest of the Dominican Republic (chapter 10), the Eastern Cape Province (chapter 4) and the Eastern miombo highlands in Southeast Africa (chapter 5). The situation, however, is not so clear for Laos (chapter 3) and the Atlantic rainforest in Southeast Brazil (chapter 8) since the results differ within the regions studied, i.e., there are good and bad prospects. Similarly, the situation turns out to be ambivalent in the case of Nepal (chapter 2) and Botswana (chapter 7), i.e., development is on the borderline and depends strongly on the near future.

Second, there are several impacts of global processes upon regional or local strategies. In Laos and the Southeast African miombo

highlands, the effects of international dam building companies and, respectively, the global tobacco market are of particular relevance.

Table 11.6 Assessment of overall risks by combining the results from climate sensitivity* and local dynamic prospects*

	Positive View	Negative View
Hotspot	Laos	Laos Cape Province Miombo Dominican Republic
Mixed	Laos Cape Province Miombo Dominican Republic	Nepal Botswana Atlantic rainforest
Good	Nepal Botswana Atlantic rainforest	Atlantic rainforest (Southeast Brazil)

* As for climate sensitivity, see Table 11.3. As for local dynamic prospects, see Table 11.5. Due to limited information, no assessment was done for the Tanzanian Maasailand and Huancar District in Argentina. When necessary, the assessment for Laos and Brazil has been split up according to the two villages investigated in each of the case studies. The more critical situation relates to the villages assessed as more critical in Table 11.5.

Third, the natural productivity of all the regions is sensitive towards climatic change. As described above, those regions where marginality is moderate and sensitivity to climate change is medium to high are in a highly critical state. We, thus, can combine this measure with the dynamic prospects (discussed first) to name particular hotspots of future evolution, i.e., the increasing risk due to climate change coincides with an endangerment due to local dynamics. Due to the somewhat ambiguous dynamical prospects, we take two different perspectives, i.e., a positive one where we assume that the dynamical behavior takes the better path, and a negative one assuming the worst possible evolution - see Table 11.5. Regions are classified as ‘hotspots’ if both contributions, i.e., climate sensitivity *and* the local dynamics, have to be assessed as critical under the

respective world-view. In this case, a strong synergetic effect has to be suspected which might dramatically endanger the livelihood of local people. If the situation is not so clear, i.e., with one aspect assessed as critical and the other as rather unproblematic, the overall region is classified as 'mixed'. In such a case, more detailed studies have to follow the assessments as provided in Tables 11.3 and 11.5. Finally some regions were grouped as rather unproblematic since none of the two indicators indicates degrees of criticality.

In total, the analysis has shown that the widespread notion, i.e., that in socio-economic terms the tropics would be worse off if climate changes, does not hold true in the form of a generalized statement. A more elaborate analysis will be necessary to carve out the prospects for different regions. The current analysis is seen to be just a first, highly aggregated step towards attaining this goal. Further work has to be done in order to refine the qualitative modelling of humankind/nature interactions.

Notes

[1] Henceforth, we refer to the different case studies by simply using the corresponding chapter numbers.

[2] Actually, all case studies collected in this volume are related to the question of land-use and land-cover. Some, but not all of them, do further refer to *changes* in land-use as a major factor of human intervention into nature.

[3] Note the medical terminology. Yet, this similarity should not be taken too literally, as, for example, the method for syndrome formulation and validation differs quite a lot between medical science and Earth System Analysis (Schellnhuber and Wenzel, 1998).

[4] Note the similarities of the Sahel Syndrome as compared to different types of the degradation-impoverishment-spiral (Leonhard, 1989; Kates and Haarman, 1992). Nevertheless, the syndrome tries to go beyond the spiral itself and more so models basic mechanisms in more detail.

[5] Formally, sensitivity is defined here as modulus of the gradient of agricultural marginality within a 36-dimensional climate space (monthly mean temperatures, monthly precipitation sum and monthly solar radiation). The resulting values are then classified into three classes, i.e., low (0-200), medium (200-400) and high (larger than 400). The values are taken relative to a monthly change of temperature of 5.13°C and of 21.5 mm in precipitation.

[6] If not stated explicitly, the evaluation refers to special case studies as reported in the single contributions of this volume, i.e., on a varying (and partly small) number of villages and households selected and investigated in larger detail. In some cases, more general information on the respective study regions could be relied upon.

[7] The case studies on the Tanzanian Maasailand and Huancar District in Northern Argentina had to be excluded since the model applied is not capable of adequately

mapping the conflicts between herders and farmers lying at the heart of the first study, while the second study contains no information on the development of natural resource properties but more so focusses upon ethnological matters.

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