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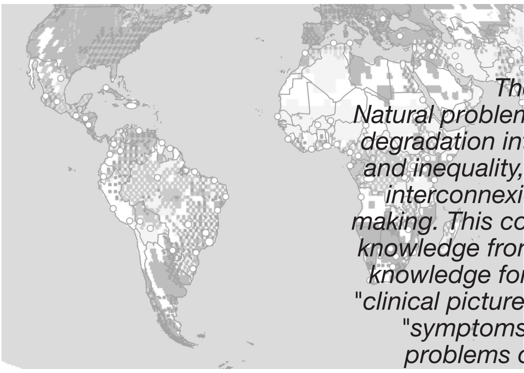

The process of global change has taken on fast and dangerous dynamics. Natural problems like climate change, biodiversity loss, limited water availability, or soil degradation interact with unsettled socio-economic developments of impoverishment and inequality, public health problems, conflicts, or policy failures. The high degree of interconnexion between these problems calls for strong scientific support for policy making. This constitutes a two-fold challenge for science: on the one hand, integrating knowledge from various disciplines and, on the other hand, producing action-oriented knowledge for mitigating global change and its effects. In analogy to medicine, major "clinical pictures" of global change have been identified. Based on indicators for major "symptoms", it is now possible to present the first panoramic synopsis of pressing problems of global change.
Abstract & Keywords ➪ p. 80

Syndromes of Global Change: The First Panoramic View

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It has become evident that we live on a human-dominated planet [1]. This fact requires new ways of thinking about ecological and environmental issues. While it has been common to analyse issues in isolation, it is now no longer applicable to take society as a "small and negligible perturbation" for the natural environment or to consider the environment as a fixed boundary condition for human society. This tightly coupled system of human civilisation and its natural environment is called the Earth System [2].

Against this background, the scientific community is confronted with new challenges. Traditional disciplinary approaches analysing individual facts or processes are no longer sufficient. Two particular challenges emerge: i) the need for integrating knowledge from various scientific disciplines and ii) the necessity for producing action-oriented knowledge to cope with, mitigate, or counteract global change and its negative effects. The first challenge can be seen as an intra-scientific problem that requires interdisciplinary approaches. The second challenge, however, pushes science beyond its traditional realm and requires that various societal actors and/or their norms and values be included in the scientific progress. This type of research is often called *transdisciplinary* research.

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In order to tackle the first challenge, various conceptual approaches have been taken within integrative interdisciplinary studies. Among these dominates the technique of modelling, which has been used widely in studies on anthropogenic climate change. Models are powerful tools that can incorporate knowledge from various disciplines, evaluate the complex interplay of processes, and assess the implications of explicit assumptions or particular actions. Models can also be used to attain strategies for actions. However, they have some shortcomings that call for additional approaches. These difficulties include the question of how to consider qualitative knowledge, as well as a "ripping of local contexts" [3], meaning that local situations can hardly be represented in a global model.

To overcome some of these shortcomings, case studies investigate regional and local aspects of global change by a combination of methods, ranging from modelling to stakeholder dialogues [4]. Yet, it often remains unclear how local and global changes interact, a shortcoming that more recently has been tackled by use of structured case study comparisons [5]. These comparisons, however, are not *per se* suitable for formulating appropriate actions against global change. There are attempts to combine this approach with the syndrome concept in order to get better applicable results [6].

The Syndrome Approach

Common to the approaches described above is their focus on a single core problem of global change, for example climate change, land use or cover change. As a consequence, any recommendations for actions based on such studies might be useless, sub-optimal or even counterproductive with respect to other problems. The syndrome approach [7] aims at a broader view of the most relevant processes of global change and seeks to preserve the local context by integrating local and regional case studies. In order to allow a global view on local and regional dynamics of environmental degradation, the approach seeks to identify *functional patterns of human-nature interaction* – patterns of processes relating human activities and environmental changes.

Within a medical metaphor, the approach focuses on clinical pictures of the Earth System. In medicine, the diagnosis of any clinical picture is not the end, but only a means for specifying an appropriate therapy for the patient. In analogy, the syndrome approach to global change is not restricted to the analysis of current trends and processes, but ultimately aims at the production and provision of action-knowledge. The syndrome approach therefore directly enters into the area of tension between scientific neutralism and normativity by addressing four different aspects: 1) What is considered as "clinical": What aspects of global change are relevant with respect to human well-being on planet Earth? 2) What typical "pictures" of those clinical situations or developments exist: What is relevant with respect to a helpful typology? 3) What determines the stability of these clinical pictures: What elements and interactions are relevant for the persistence of these pat-

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Table 1. 16 syndromes of global change as assessed by the German Advisory Council on Global Change [44].

Syndrome name	Short description of the mechanism
Utilisation syndromes	
Sahel Syndrome (*)	Overcultivation of marginal land.
Overexploitation Syndrome (*)	Overexploitation of natural ecosystems.
Rural Exodus Syndrome	Environmental degradation due to abandonment of traditional agricultural practices.
Dust Bowl Syndrome (*)	Non-sustainable agro-industrial use of soils and water.
Katanga Syndrome	Environmental degradation due to depletion of non-renewable resources.
Mass Tourism Syndrome	Development and destruction of nature for recreational ends.
Scorched Earth Syndrome	Environmental destruction due to war and military action.
Development syndromes	
Aral Sea Syndrome (*)	Environmental damage to natural landscapes as a result of large-scale projects.
Green Revolution Syndrome (*)	Environmental degradation due to un-adapted farming methods.
Asian Tiger Syndrome (*)	Disregard for environmental standards in the context of rapid economic growth.
Favela Syndrome (*)	Environmental degradation due to uncontrolled urban growth.
Urban Sprawl Syndrome	Destruction of landscapes due to planned expansion of urban infrastructure.
Disaster Syndrome	Singular anthropogenic environmental disasters with long-term impact.
Sink syndromes	
High Stack Syndrome	Environmental degradation as a result of large-scale dispersion of emissions.
Waste Dumping Syndrome	Environmental degradation due to controlled and uncontrolled waste disposal.
Contaminated Land Syndrome	Local contamination of the environment at industrial locations.

The syndrome names either sketch the main mechanism involved or represent a paradigmatic area where the respective mechanism can be observed. The syndromes are classified into three groups, reflecting the general properties of their underlying mechanism. The seven syndromes indicated with an asterisk are included in the panoramic view presented in this paper.

terns, or syndromes, of global change? 4) What strategies can be devised to mitigate or prevent syndromes: What are relevant intervention points to interrupt the stabilisation process of syndromes?

Ideally, the syndrome approach is realised within an abduction process [8] that simultaneously seeks to conclude statements regarding the four aspects. The abduction is based on local case studies that are analysed in a more [6] or less [9] formal way. The present formulation of syndromes, however, considers the fourth aspect – developing strategies for action – only implicitly. The syndrome diagnosis presented in this paper can therefore only be seen as a first step. Nevertheless, we will discuss the results also with respect to syndrome mitigation or prevention.

The analysis of an individual syndrome can already give interesting insights into important issues of global change. Yet it is the panorama of all the syndromes that yields a complete picture of the present state of the "planet's health". In this paper we attempt to give a first – preliminary and restricted – panoramic view of seven syndromes. We specify the methods used for indication, or diagnosis, of syndrome intensities and present a world map showing the geographical distribution of basic patterns of non-sustainable development.

Seven Syndromes of Global Change

The syndromes included in this study comprise major extractive and development activities, which on basis of broad experience can be considered as problematic according to aspect 1) in the previous section. Here, we consider activities with respect to regenerative resources, industry and urban agglomerations.[1)] Other syndromes related, for example, to sink problems like the one caused by fossil CO_2 emissions, to urban sprawl in industrialised countries or to environmental impact of mass tourism are presently under investigation and will complete the global picture in the near future (Table 1).

Sahel Syndrome

The *Sahel Syndrome* relates to failures of reproduction-oriented smallholder agriculture in developing countries. In large areas, poverty-induced resource overuse, resource degradation and yield losses create a spiral of non-sustainable development. This mechanism may be reinforced by land divisions due to population growth and inheritance, and by displacement of people [11]. Increase in poverty and land degradation often end in hunger, migration, or violence. Smallholder agriculture becomes "syndromatic" if a) the farmer works on *marginal land*, where resource degradation – induced by poverty-motivated intensification of agricultural activity, for example reduction of fallow periods – usually overcompensates any yield increase gained by intensification, and b) there are *no alternative sources of income*, which forces land managers to seek to ensure their livelihood via intensification of *on-*farm activities. Together, these two factors form a trap within the impoverishment-degradation spiral [9, 12].

To identify the world's regions affected by the *Sahel Syndrome* in the 1990s, global data on the rate of soil degradation and on the change in rural poverty and agricultural activity were used. To improve spatial resolution, we additionally applied the condition that a region must be disposed towards the syndrome due to agricultural marginality [13] and insufficient availability of off-farm employment.

Dustbowl Syndrome

This syndrome is related to another form of agricultural intensification in

[1)] Three of the seven syndromes occur only in developing countries, one is related to newly industrialising countries, and the remaining three syndromes occur in both industrialised and developing countries. The selection is due to pragmatic reasons only and leads to a somewhat more detailed exploration of non-sustainability in the developing countries. By this we do not intend to impute a minor role of the industrialised parts of the world in global change, and we consider it difficult to quantify the respective roles of industrialised and developing countries. For example, although the majority of fossil CO_2 emissions (*High Stack Syndrome*, see Table 1) is generated by industralised countries, the *Asian Tiger Syndrome* contributes considerably to the CO_2 emissions, and even the *Overexploitation* and *Sahel* (CO_2), *Dust-Bowl* (CO_2, CH_4, NO_x) and *Green Revolution* (CH_4) *Syndromes* are relevant in the context of greenhouse gas emissions [10].

developing and industrialised countries [14] and occurs when capital-intensive and profit-oriented agricultural overuse brings about soil and environmental degradation. This in turn can result in yield losses, motivating farm managers to apply increased amounts of chemical fertiliser and/or intensively irrigate their fields. This non-sustainable path is characterised by a high level of or strongly increasing capital-oriented agricultural intensification (automation, application of chemicals, intensive irrigation) and/or high livestock densities. This comes along with high involvement in international trade and decreasing labour intensity [15]. The severe soil erosion in the 1930s that transformed the West of the United States into a "Dust Bowl" shows paradigmatically how agricultural intensification interacting with climate variability – here: a historic drought – may degrade agricultural resources. This syndrome occurs in regions with favourable natural conditions for agriculture or livestock and high accessibility by train, road or ship, which allows good market access. This can be seen, for example, in developing countries where market-oriented largeholders or agricultural companies occupy the more productive sites such as river valleys.

To identify the world's regions affected by the *Dust Bowl Syndrome*, global data on the intensity of agricultural use were compared with different intensity-thresholds, resulting in an indication of agricultural overuse. This was complemented with global data indicating market orientation and labour extensiveness of agriculture and with accessibility data (roads, train tracks, rivers, harbours) as well as data on the spatial distribution of regions with favourable natural conditions for agriculture [13].

Green Revolution Syndrome

A third variety of agricultural intensification is related to (politically) planned agricultural development in developing countries that aims at ensuring national food security. Though not originally envisioned, an increase in agricultural exports was a major secondary effect of the program. This process known as the Green Revolution brought a substantial increase in food production since the 1960s, particularly in Asia, and it succeeded to avert large-scale famines that otherwise would have been an impending threat to many developing countries. However, it originally had severe negative side effects on production conditions and social structure [16] because the extensive, centrally planned and rapid agricultural modernisation with imported agricultural technology such as high-yielding crop varieties, planned from a mainly supply-oriented point of view, was not adapted to local conditions. This process can generate a critical path characterised by rural poverty and/or national debt along with soil degradation on cereal production sites, so that the achieved increase in agricultural productivity is difficult to sustain [17]. Green Revolution technology therefore might not ultimately solve the malnutrition problem in some parts of the world.

To identify the world's regions affected by the *Green Revolution Syndrome*, global time series on rural poverty, degradation/salinisation rates in naturally

Table 2. Seven syndromes of global change, along with their respective underlying functional patterns of human-nature interaction and their disposition factors (conditions under which the respective syndrome occurs).

Syndrome name (abbreviation)	Underlying functional pattern	Syndrome description	Disposition factors
SAHEL (S)	Reproduction-oriented smallholder agriculture.	Downward spiral by mutual reinforcement of resource degradation and impoverishment [9].	Marginal land (Sd1); no alternative income sources (Sd2).
DUST BOWL (D)	Profit-oriented capital-intensive agriculture.	Soil and environmental degradation due to capital-intensive, profit-oriented overuse and extensive application of chemicals; decreasing labour intensity and/or induced land pressure on smallholders [15].	Profitable soil or pasture conditions (Dd1); accessibility by train/road/ship (Dd2).
GREEN REVOLUTION (G)	Ensuring food self-sufficiency in developing countries.	Environmental degradation and growing socio-economic disparities due to non-adapted agricultural techniques (high-yielding varieties) introduced by governments [7].	Malnutrition (Gd1); cereals a relevant fraction of national diet (Gd2).
OVER-EXPLOITATION (O)	Extraction of renewable resources.	Vegetation and soil degradation due to profit-oriented overuse of renewable resources, mainly forests; policy failures with regard to stopping or regulating the exploitation [19].	Accessibility and usability of forests (Od1); national dependency on wood export (Od2).
ARAL SEA (A)	Centrally planned large-scale water schemes.	Environmental degradation, socio-economic problems, and (international) conflicts caused by dams and irrigation schemes [17].	Tendency towards top-down project planning and purely technological solutions.
ASIAN TIGER (T)	Rapid economic growth in developing or newly industrialising countries.	Severe pollution and health problems due to rapid industrialisation without regard for environmental standards [22].	World market accessibility (Td1); pronounced work ethic.
FAVELA (F)	Unplanned urbanisation in developing countries.	Pollution and health problems in rapidly growing urban areas due to lacking infrastructure development [23].	Absence of rural development.

favoured agricultural regions, national debt, cereal productivity and domestic cereal consumption, nutrition of the population and the role of cereals in the diet were used.

Overexploitation Syndrome

In contrast to the above patterns that dealt with agriculture, the *Overexploitation Syndrome* relates to the profit-oriented extraction of renewable resources, mainly wood extraction from the world's forests and woodlands. Overexploitation of these ecosystems results in – sometimes irreversible – ecological regime shifts, soil degradation and/or destruction of indigenous livelihoods [18, 19]. The process is fuelled by widespread corruption that fosters exploitation of *ipso jure* protected forest areas or prevents any protection efforts. The non-sustainable path is characterised by large or strongly increasing quantities of round timber or fuel wood extraction combined with policy failure, for example lacking enforcement of natural protection laws, or corruption. This mechanism occurs in countries with easily accessible forests or woodlands and timber being a primary source of national income.

To identify the world's regions affected by the *Overexploitation Syndrome*, global data on round timber production and the ratio of wood export to total export, the Transparency International Corruption Indicator, the Forest Action Plan Indicator and data on national debt service were taken into account. Spatial resolution was improved by data on woody biomass density and accessibility of forest areas by roads and rivers.

Aral Sea Syndrome

This syndrome refers to large-scale water schemes such as dams, river diversions or irrigation schemes [20]. Although they may provide water, renewable energy, flood control, or navigation, they often have severe impacts on the environment and on society [21]. The effects are rarely confined to a local or regional scale, but can take on far-reaching and even international dimensions, for example possibly violent conflicts over water. On each site, one can observe degradation of ecosystems, significant alterations in sediment transport, increasing health risks, for example by vector-borne diseases, fresh water loss by additional evaporation, and international conflicts on boundary rivers [17]. The number of large-scale water schemes is continually rising, promoted by international institutions like the World Bank. This development becomes problematic since access of the concerned population to information on environmental and societal side-effects – caused, for example, by resettlements – is often limited and participation in and transparency of the planning process is restricted. The syndrome occurs if there prevails a tendency towards top-down project planning and if large-scale technologies are promoted. It should be noted, however, that recent efforts in form of new private-public partnerships seek to overcome many of these side-effects.

To identify the world's regions affected by the *Aral Sea Syndrome*, two basic global data sets were applied: the river discharge on a half-degree grid and a list of dams more than 30 meters high. The combination of the two allowed for an assessment of the degree of human influence on surface water dynamics. The spatial overlapping of high human influence and high natural sediment transport, high climatic risk of bilharzia, and ecologically valuable wetlands indicates the activity of the syndrome.

Asian Tiger Syndrome

This syndrome is associated with rapid, export-oriented industrialisation in developing or newly industrialising countries, where all profits are fed back into additional industrial growth while domestic consumption remains relatively low. The pattern becomes syndromatic if environmental standards are – sometimes deliberately – disregarded, which may induce a multitude of environmental damage such as severe pollution of all media, health problems and large-range destruction of forests [22]. The syndrome is facilitated by good infrastructural access to the world market, for example in coastal areas, and a pronounced work ethic amongst the population.

To identify the world's regions affected by the *Asian Tiger Syndrome*, global time series of national industrial gross domestic product and, as an indicator for all pollutants, industrial CO_2 emissions were used. Further spatial specification was possible by analysing the proximity to the coast and large harbours.

Favela Syndrome

Urbanisation in developing countries is often accompanied by rapid and uncontrolled urban population growth, which leads to environmental pollution and health problems due to lacking infrastructure resulting from limited public budgets and/or policy failure [17]. This non-sustainable path is characterised by high urban population growth, insufficient urban sanitation or water supply services, a large or increasing number of urban poor, and low public investment [23]. A condition for this syndrome is the absence of rural development, which makes the rural poor move to the cities.

To identify the world's cities affected by the *Favela Syndrome*, global time series on urban population, urban poverty, access to sanitation services and safe drinking water, and the ratio of public investments in infrastructure to total public investments have been used.

Table 2 gives an overview of the seven syndromes described above.

Method of Syndrome Indication

For a syndrome to be diagnosed in a specified region, the respective non-sustainable development path must be observable. Such a path is characterised by a particular combination of trends as reported for each of the investigated syndromes in the previous section, for example a simultaneous increase of rural poverty, land degradation, and agricultural activities in case of the *Sahel Syndrome*. These trends can be detected by appropriate indicators. Qualitative indicators expressed by attributes like "high" need further formalisation. It is obviously inappropriate to apply a sharp numerical limit, for example: the statement "urban population growth is high" is true (=1) if it is above 3.5 percent per year and false (=0) if it is below 3.5 percent per year. Therefore, the fuzzy logic approach appears more adequate [24]. Here, continuous truth values between 0 and 1 are introduced together with logical connectives that reproduce the Boolean logic in the respective limit cases. The "AND" connective, for example, can be represented by taking the minimum of two truth values, while "OR" takes the greater of two truth values. In a first step, we mapped the quantitative indicators of Table 3 onto truth values of the respective statements (Figure 1).

In a second step, these truth values were combined with the apparently most appropriate connectives, for example "AND" or "OR". The result of this process based on several qualitative indicators is the truth value x = [0, 1] of the statement "the non-sustainable path is observed in the respective region". The same method was applied to identify the different disposition factors, which were used for further specification of the syndrome regions.

For the seven syndromes discussed in the previous section, the indicator-based identification of their global distribution and, in part, of their disposition factors was performed in several studies in the framework of the PIK syndromes project. The time around 1990 was chosen because of its broad data availability, in particular concerning socio-economic trends. Table 3 gives an overview of the information base employed. For a comprehensive description of the identification algorithms (such as fuzzification parameters, applied connectives, verification) we refer to the respective publications (see Table 2).[2)]

Global Distribution of Syndromes

The result of the syndrome indication process is displayed in Figure 2. A syndrome was considered as present when the truth value for its occurrence was above 0.2. It should be taken into account that the gaps in data availability denoted in the figure caption signify that the map shows the occurrence of syndromes with greater certainty than their absence.

The *Dust Bowl*, *Overexploitation* and *Aral Sea Syndromes* prevail in industrialised countries. The *Dust Bowl Syndrome* dominates the map for Europe, the former Soviet Union and the United States and is the most widespread syndrome in temperate as well as more arid zones in Spain and the Western USA. Despite large variety in both the economic system and the natural conditions for agriculture, high agricultural intensity

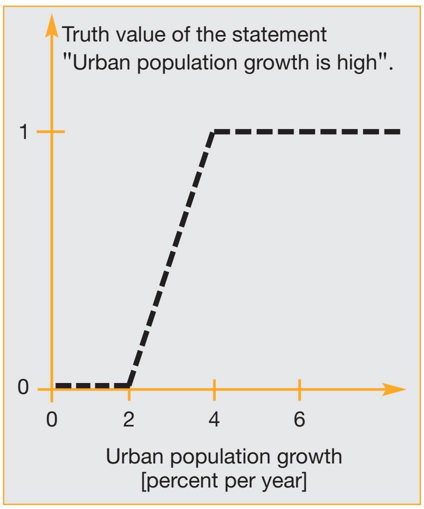

Figure 1. Exemplary "fuzzification" of the qualitative indicator "urban population growth" with respect to the statement "urban population growth is high". Fuzzification allows to allocate continuous truth values to qualitative indicators such as "high"; a sharp numerical limit – for example "urban population growth is high" is true (=1) if it is above 3.5 percent per year and false (=0) if it is below 3.5 percent per year – would be inappropriate.

that generates severe consequences for the environment and the resource base is identified all over the industrialised part of the world. It obviously does not matter if the incentive for over-intensification lies in the profits of individual farmers in partly regulated markets (Europe and United States) or in the production objectives of the centrally planned economy of the former Soviet Union. The *Dust Bowl Syndrome* is not restricted to regions naturally favourable for agriculture, but invades also marginal areas of industrialised countries. The West of the USA, the South of Spain and Italy as well as Greece overcame their aridity-imposed limitations to agriculture by intensive irrigation, either overusing their limited groundwater resources or generating further problems by extensive river regulation. This latter consequence triggers the *Aral Sea Syndrome*. The map shows the correlation of these two syndromes in Southern Europe while it is not identified [3)] along the Colorado river in the USA, although it is an intensively discussed issue there. The *Overexploitation Syndrome* applies to tropical and boreal forests and also, to some extent, to the forests of temperate regions. Due to a major data gap, the map does not show this syndrome in Siberia, although overexploitation of Siberian forests exists.

The *Sahel Syndrome* was found in large areas of Latin America, Sub-Saharan Africa, in arid zones of Northern Africa and Asia as well as South and East Asia. Outside the large regions where this syndrome predominates, one observes three typical combinations with other syndromes: with the *Overexploitation Syndrome* in the Amazon Basin and Central Africa, with the *Dustbowl Syndrome* in South-Eastern Brazil as well as East and South Africa, and with the *Green Revolution Syndrome* in India. The coexistence of the *Dust Bowl* and *Sahel Syndromes* in the East of Brazil suggests that they are linked or reinforce each other due to problematic smallholder-largeholder relations, where economic and political marginalisation keeps smallholders in the impoverishment-degradation cycle.

The *Green Revolution Syndrome* is typically paired with the *Aral Sea Syndrome*, for example in India, which can be explained by the high irrigation demand of high-yielding cereal varieties. Several multiple-syndrome "hotspots" can be identified, for example the region around Mexico City that is affected by the *Green Revolution*, *Dust Bowl*, *Overexploitation*, *Aral Sea* and *Favela Syndromes*. The same combination can be seen in parts of Southeast Asia.

Discussion

Global data collections on single aspects, such as soil degradation, distribution of wealth and poverty, or fossil CO_2 emissions are important for identifying dangerous trends of global change but can hardly provide information about the mechanisms that bring them about. Therefore, they are only of limited use for developing strategies for sustainability management. To solve this problem, the syndrome concept presented here offers a plausible typology of typical patterns of problematic civilisation-nature interactions. The map presented in this study (Figure 2) represents a step towards an advanced and comprehensive functional understanding and mapping of global environmental change. It should be stressed that the indication procedures presented here are to a large extent governed by limited availability of global data. Due to this limitation, the "measurement" of a syndrome often reflects the process only indirectly.

The following action-oriented lessons can be drawn from the present analysis: Due to the system-theoretic basis of each syndrome, actions for mitigation of an individual syndrome comprise a set of political, economic, legal, or other measures. These measures can be classified according to whether they help to reduce the syndrome's disposition, whether they seek to modify the syndrome mechanism or the severeness of a syndrome. Consider, for example, the measures against the *Aral Sea Syndrome* as recommended by the German Advisory Council on Global Change [17]. As part of a three-step strategy, the council firstly recommends to reduce the disposition, for example by improving irrigation efficiency or by alterating land use in order to improve flood prevention. In a second step, some "knock-out criteria", for example a threshold value for vector-borne diseases, are formulated: if they are fulfilled, this forbids a large-scale water scheme. In a third step, if a large-scale water scheme is still seen as the best

[2)] A severe problem is data coverage, although gaps in the input data must not necessarily lead to totally uncertain results of the indication algorithm. Depending on the values of the available indicators and the connectives used, the result is sometimes insensitive with respect to missing data.

[3)] This is due to a regional shortcoming in the global surface runoff model and the data on large dams used in the indication algorithm of the *Aral Sea Syndrome*.

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Table 3. 56 indicators used for the identification of syndrome-specific non-sustainable paths and disposition factors (for abbreviations refer to Table 2).

Indicator	Used for syndromes/ disposition factors	Spatial resolution	Time span	Source
Rural poverty headcount index	S, G	national	mid 1980s, early 1990s	[25, 26]
Severity of anthropogenic soil degradation	S	FAO soil type polygons	mid 1980s	[27]
Rate of anthropogenic soil degradation	S	FAO soil type polygons	mid 1980s	[27]
Total number of cattle, sheep, goats	S, D	national	1985, 1992	[28]
Arable land area	S, D	national	1985, 1992	[28]
FAO soil type	Sd1, Dd1	0.5° x 0.5° grid	present	[29]
Slope of the land	Sd1, Dd1, Od1, Td1	0.5° x 0.5° grid	present	[30]
Productivity of natural vegetation (modelled)	Sd1, Dd1	0.5° x 0.5° grid	recent climatology	[31]
Labour force in agriculture, absolute total labour force	Sd2, D	national	early 1990s	[28]
Production, import and export of food crops according to market statistics	Sd2	national	early 1990s	[32]
Number of harvesters, tractors	D	national	early 1990s	[32]
Fertilizer and pesticide consumption	D	national	early 1990s	[32]
Irrigated area	D	national	early 1990s	[32]
Amount of irrigation water used	D	national	early 1990s	[28]
Export fraction of agricultural production	D	national	early 1990s	[32]
Pasture and rangeland area	D	national	early 1990s	[32]
Productivity of rangeland area (modelled)	D	0.5° x 0.5° grid	recent climatology	[33]
Population density	Dd2, Od1	0.5° x 0.5° grid	early 1990s	[34]
Fraction of urban population	Dd2, Od1	national	1992	[28]
Transportation network	Dd2, Od1	vector	present	[35]
Cereal production area	G	national	early 1990s	[32]
Cereal productivity (yield per area)	G	national	1960–1992	[32]
Cereal production (absolute yield)	G	national	1960–1992	[32]
Average calorie supply per person	Gd1	national	1960	[32]
Fraction of cereals in diet	Gd2	national	1992	[32]
Cereal exports	G	national	1960–1992	[32]
National debt service	G, O	national	1960–1992	[36]
Round timber production	O	national	1988–1992	[37]
Forest action plan indicator	O	national	mid 1990s	[37]
Corruption index	O	national	1988–1992	[38]
Woody biomass density (modelled)	Od1	0.5° x 0.5° grid	early 1990s	[39]
Wood export/total export	Od2	national	1988–1992	[37]
River discharge (modelled)	A	0.5° x 0.5° grid	recent climatology	[12]
Dams over 30 m high	A	provinces	late 1980s	[40]
Natural sediment transport (modelled)	A	0.5° x 0.5° grid	recent climatology	[17]
Wetland areas	A	1° x 1° grid	present	[41]
Risk for bilharzia (modelled)	A	0.5° x 0.5° grid	recent climatology	[17]
Aridity coefficient (modelled)	A	0.5° x 0.5° grid	recent climatology	[42]
Gross domestic product	T	national	1970–1992	[36]
Industrial fraction of gross domestic product	T	national	1970–1992	[36]
Amount of CO_2 emissions	T	national	1970–1992	[28]
Distance from coast	Td1	0.5° x 0.5° grid	present	[30]
Urban poverty headcount index	F	national	mid 1980s, early 1990s	[25, 26]
Urban population number	F	national	mid 1980s, early 1990s	[28]
Fraction of urban population with access to sanitation services	F	national	1980, 1993	[43]
Fraction of urban population with access to safe water	F	national	1980, 1993	[43]
Public investments in infrastructure	F	national	early 1990s	[36]
Total public investments	F	national	early 1990s	[36]

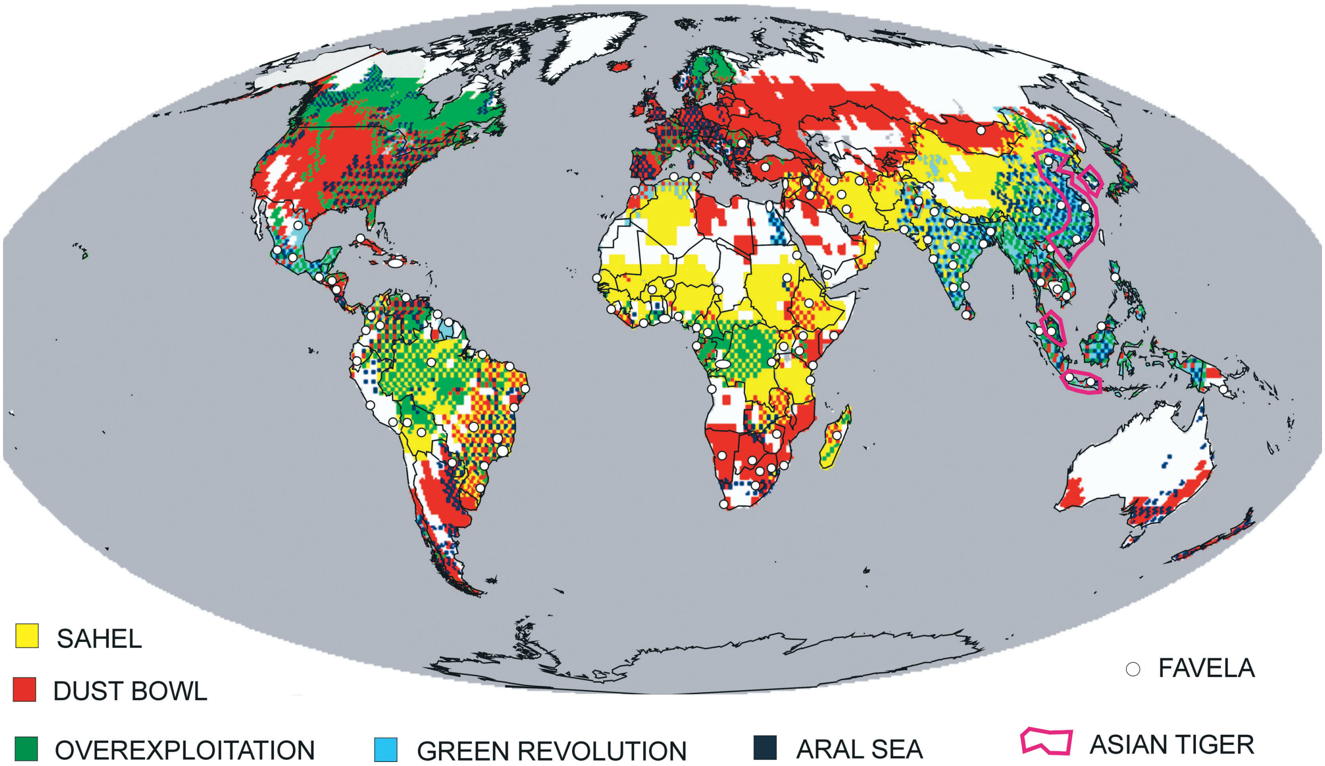

Figure 2. Global distribution of seven syndromes. Syndrome names are given in the legend. Simultaneous occurrence of more than one syndrome in a spatial map unit (2 degrees of latitude by 2 degrees of longitude) is symbolised by a chequered pattern combining the colours of the syndromes involved (the finest original resolution for a single syndrome is 0.5 by 0.5 degrees). The light grey land areas are either syndrome-free with respect to the seven investigated syndromes, or potential syndromes could not be identified because of significant gaps in data availability. While the indication of the *Dust Bowl*, the *Green Revolution* and the *Asian Tiger Syndromes* has global coverage, some gaps exist for the other four syndromes due to absence of or unreliable data. This refers, for example, to all four syndromes with respect to Russia, to the *Aral Sea* and *Sahel Syndromes* in some regions of Africa and the *Overexploitation Syndrome* in parts of Central America.

solution to the pressing problems, the damage should be kept as low as possible, for example by releasing sufficient water from a reservoir to preserve the downstream ecosystem. Such measures can also serve as a strategy for better management in cases when the syndrome is already active. This three-step action program suggested within the syndrome approach again finds its analogue in medicine and corresponds to prevention (steps one and two), pain relief (steps two and three) or even cure. This structuring of measures goes beyond the recommendations made by other approaches and helps to structure the political options.

Analogous to medicine, things become more subtle and difficult if more than a single syndrome has to be treated. Consider, for example, the combined occurrence of the *Sahel* and the *Overexploitation Syndromes* in the Amazon Basin. The *Overexploitation Syndrome* actually serves as an exposition factor for the *Sahel Syndrome* [19]: Roads and infrastructure originally constructed by logging companies serve as access lines for smallholder settlers, thereby further promoting forest destruction and soil degradation. Therefore, any therapy devised to mitigate the *Overexploitation Syndrome* may also reduce the disposition for the *Sahel Syndrome*. However, the opposite can be true, when measures designed to mitigate one syndrome aggravate another syndrome: for example, measures that slow down economic growth, designed to mitigate the *Asian Tiger Syndrome*, might aggravate the *Favela Syndrome*.

The syndrome approach provides a helpful overview about main processes of global environmental change. It represents an indicator-based attempt to inform all actors – the scientific and political communities and the involved public – about critical developments with regard to sustainability. Based on this present-state diagnosis, it is possible to develop and assess options for mitigating syndromes. Yet the syndrome approach goes beyond this by incorporating model-based knowledge; it uses, for example, natural primary productivity as modelled by various process-based global vegetation models. This allows to assess various scenarios such as the potential occurrence of syndromes under climate change [12] and to propose appropriate actions at an early stage.

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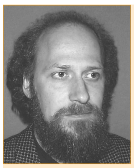

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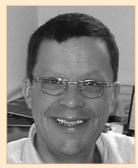

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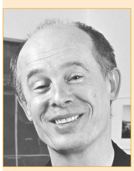

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