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SECURITY DIAGRAMS: IMPROVING OUR UNDERSTANDING OF THE RISK OF EXTREME CLIMATE EVENTS TO SOCIETY

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Summary

The objective of this project is to improve the estimation of vulnerability to drought by analysing and comparing differences between three distinct disciplinary perspectives (economics, political science, and behavioral science/environmental psychology). To make this comparison we developed a new methodology for quantifying susceptibility which consisted of (i) translating qualitative knowledge into inference models, (ii) converting qualitative model variables into quantitative indicators by using fuzzy set theory, (iii) collecting data on the values of the indicators from case study regions, (iv) inputting the regional data to the models and computing quantitative values for susceptibility. The methodology was successfully applied to three case study regions having a range of socio-economic and water stress conditions -- Andhra Pradesh, India; Algarve and Alentejo, Portugal, Volgograd and Saratov, Russia. Bottom-up survey data and top-down statistical data were collected from each region and input to the models and quantitative estimates of susceptibility were computed. This is perhaps the first attempt to compare quantitative estimates of susceptibility to drought from three different disciplinary perspectives. In some cases the estimates of susceptibility were surprisingly similar, in others not, depending on the factors included in the disciplinary models and their relative weights. For example, both the psychology and economics perspectives compute the susceptibility of the Russian and Portuguese regions to be about the same, but because of different factors. The methodology provides a consistent basis for comparing differences between perspectives, and for identifying the importance of the differences.

A crisis data set was also developed for the case study regions as a basis for independently testing vulnerability estimates and identifying thresholds. The data set consisted of the year of occurrence of drought-related crises in the case study regions, and was based on an extensive media analysis. The crisis data set was used to test 14 different water stress indicators, and 6 of these were found to be statistically significant. A new aggregate water stress index based on 3 other indicators was found to have a higher statistical significance than the other individual indicators and seems to be applicable to a wide range of water stress situations.

1. Aim of the research in the framework of DEKLIM

The main objective of this project is to improve the estimation of vulnerability of society to extreme climate events through a better understanding of the differences between disciplinary viewpoints. It is thought that a better understanding of these differences will lead to a synthesis of important insights from the different disciplines. The focus of the project is on vulnerability of the population of a region to drought. To better compare disciplinary views we divide the vulnerability concept into three component parts[1] (i) the "susceptibility" of society (i.e. the converse of adaptive capacity), which is a function of attributes of society such as it preparedness for disasters, (ii) "water stress" which is a reflection of nature's pressure on society, and (iii) drought-related societal "crises". This is the division proposed by Alcamo (2001) and Alcamo and Endejan (2001) in the analytical tool called "security diagrams".

The approach of the project is to quantify and compare these concepts in a standardized way using data from three contrasting case study regions --Andhra Pradesh, India; Algarve and Alentejo, Portugal, Volgograd and Saratov, Russia. These regions cover a wide range of socio-economic and water stress conditions.

The main activities of the project were as follows: First, a methodology was developed to model and quantify susceptibility. This methodology was used to produce and compare estimates of susceptibility from three different disciplinary perspectives. Next, a crisis data set for the case study regions was compiled in order to independently test estimates of vulnerability. Finally, the crisis data were used to test the validity of various water stress indicators and their thresholds.

2. Recent and completed activities

Extensive "top-down" and "bottom-up data" were collected from the study regions. Top-down data included, for example, statistical data of various economic and demographic indicators, and cover from 1980 to 2000. Bottom-up data consisted of targeted survey data concerning the capacity of residents of the case study regions to cope with drought, and refers to conditions in the late 1990s. The data were used for the analyses described in the following sections of this paper.

3. Results – Quantifying Susceptibility

3.1 New Methodology for Quantifying Susceptibility from Several Disciplinary Perspectives

A central objective of this project is to elaborate and compare the concept of susceptibility from three distinct disciplinary perspectives – economics, political science, and behavioral science/environmental psychology. For this task we developed a new methodology to

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[1] Working definitions of *susceptibility, water stress and crisis* as used in this report are adapted from Alcamo (2000). They are all given in the context of environment and security. (1) *Susceptibility* -- the capability of an individual, community, or state to resist and/or recover from crises brought about by environmental stress.(2) *Transient environmental stress* (of which *water stress* is taken as a sub-category) -- the intensity of an environmental change that (i) involves an undesirable departure from long-term or "normal" conditions, (ii) is of short duration (iii), is directly or indirectly influenced by society, and not only the result of natural geologic factors (as in the case of volcanoes and most earthquakes). *(3) Crisis* -- an unstable or crucial time or state of affairs brought about by environmental stress in which a decisive and undesirable change is impending or occurring, and which requires extraordinary emergency measures to counteract.

quantify susceptibility from different disciplinary viewpoints. This new methodology is one of the main results of the project and has potentially wide application outside of this project for numerically estimating the susceptibility of a population to drought and other extreme climate events. The main effort of this project was devoted to developing and applying this methodology.

The methodology consists of the following components:

1. *Developing inference models* – The first step is to translate qualitative knowledge into verbal statements. This could be knowledge from a social science theory or construct, or observation. Usually the statements are in the form of assertions, as in "If public expenditures on health care are high, then susceptibility tends to be low." The different verbal statements are then related together in statements such as "If public expenditures on health care are high, and if expenditures on infrastructure are high, then susceptibility is low". Examples of these relations are graphically depicted in Figures 1, 3, and 5. Measurable (or at least estimatable) indicators are selected for each element of the statements. For example, as an indicator of public expenditures we used the percentage of GDP of public expenditures on education and health and for infrastructure the irrigated areas as percentage of total crop land**.** Data on these indicators are later collected from the case study regions. We developed separate inference models for behavioral science/environmental psychology, economics, and political science, as described in Sections 3.2, 3.3 and 3.4 of this paper.
2. *Quantifying the models with fuzzy set theory* – Fuzzy set theory is then used to convert expert opinion about "high" "low" and "medium" in the inference model into numerical values. Fuzzy set theory is also used to weight one set of factors versus another so that a final quantitative value for susceptibility can be estimated.
3. *Collecting data* – The values of indicators in the inference model are then measured or estimated in the case study region. "Top-down" statistical data are used for the economics and political science models, and "bottom-up" survey data for the environmental psychology model.
4. *Computing susceptibility* – Data collected in the previous step are input to the models and a quantitative value for susceptibility is computed.

This methodology has the advantage of helping to fill typical gaps in numerical data with local and expert knowledge. Moreover, it provides a way to compute and compare estimates of susceptibility from very different disciplinary perspectives. The next four sections describe the development and results of the disciplinary models.

3.2 Susceptibility Model from Psychology Perspective

The inference model of susceptibility from the psychological perspective is based on the concept of "agents" and their subjective assessment of a threatening situation. This assessment determines the agents' actions and hence their susceptibility. The approach follows the often stressed necessity to consider the "internal side" of vulnerability (Bohle, 2001; Chambers, 1989; Kasperson & Kasperson, 2001). Agents are groups of individuals such as households. The inference model is based on protection-motivation-theory (Rogers, 1983; Rippetoe and Rogers, 1987) successfully applied in the risk-health area (Milne, 2000). Following from this theory, susceptibility can be defined as the lack of protection capacity of agents. A high protection capacity and therewith a low susceptibility is given if agents think the situation is threatening but they believe they can cope with it. To measure the relevant factors we conducted interviews with selected households in the case study regions.

The more threatening the agents think the situation is, the more intensively they look for coping strategies. Hence, they are potentially better prepared for coping and conversely less susceptible. However, if the exposure to a drought situation is felt to be extremely high, hardly any possible coping strategy is sufficient to deal with that extreme situation and consequently susceptibility increases. Thus the relationship between the appraisal of threat and susceptibility is curvilinear.

According to protection-motivation-theory and empirical findings for drought-related susceptibility (Devereux & Naeraa, 1996; Johnson, 2000; Liverman, 2000, Rahmato, 1991, Spittler, 1994) the appraisal of threat is higher the higher is the net assessment of negative consequences of drought, the more the income and food supply of household depends on the agricultural sector, the higher is the dependency ratio (ratio of non-working persons to working persons), and the more central values are threatened (for example health, dignity, material belongings).

In addition to the appraisal of threat, the appraisal of coping capacity is important since the higher this appraisal, the lower the susceptibility. The ability to cope with a situation is high when agents have access to (agrarian and non-agrarian) "resources". The appraisal of coping capacity is higher when technical or "at place" measures (e.g. changing food consumption) are available, and when barriers to obtaining assistance (e.g. institutional impediments) are low.

These various factors are related to one another in the inference model as shown in Figure 1.

Figures 2 and 7 shows the most important results for the 3 case study regions. The interviewed people in Andhra Pradesh in India are highly susceptible (0.7), mainly because they are highly exposed to drought impacts and have not enough resources and too many barriers to implement successful coping measures. The interviewed people in the Russian and Portuguese regions show low susceptibility (0.4, 0.3), but because of different reasons. In southern Portugal people do not have enough resources in particular to implement technical measures in case of drought. In the Volga basin in Russia people are much more dependent on agriculture and have not enough resources to compensate losses in agriculture in case of drought.

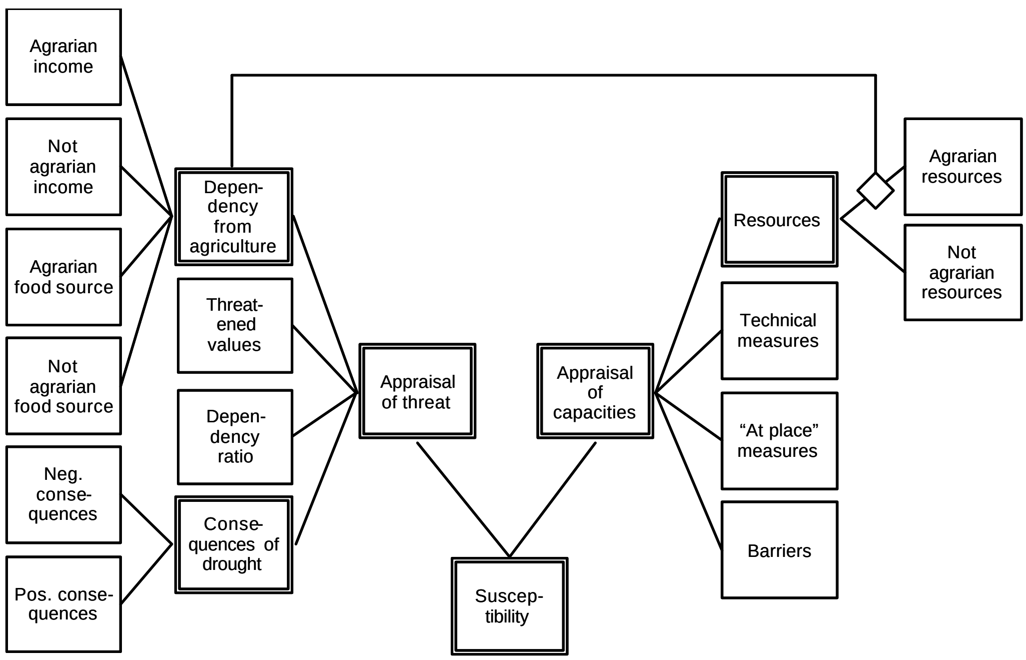

Figure **1.** Theoretical model of susceptibility from psychological perspective.

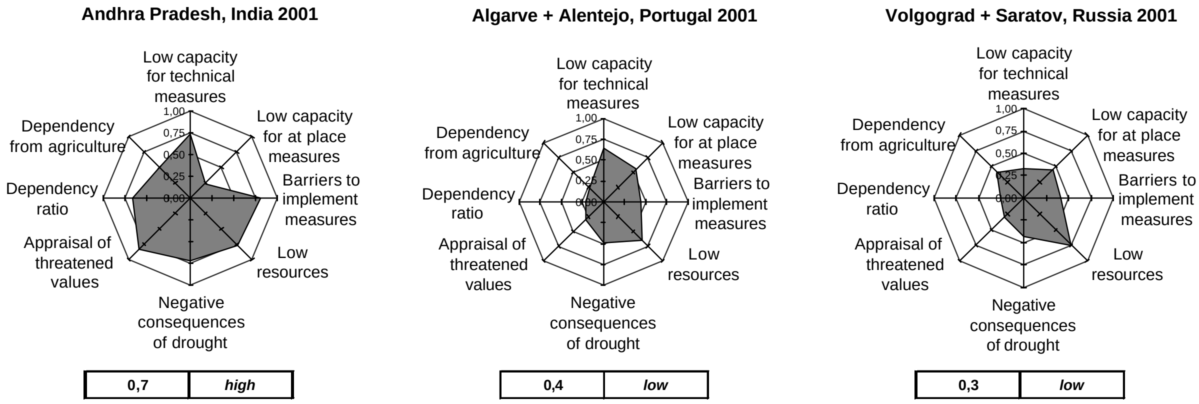

Figure **2.** Influence factors of susceptibility from psychological perspective.

3.3 Susceptibility Model from Socio-economic Perspective

The susceptibility model from the socio-economic perspective is based on the idea that susceptibility is related to the inability of the state and free market to provide sufficient economic and social resources to society for coping with water stress. The model is related to the concept of "double exposure" (O'Brien and Leichenko 2000) which suggests that regions characterized by economic marginalization and high-risk environments may be potential "double losers". The specific relationships depicted in the model are derived from the economic development theories of "modernization" and "dependency".

Modernization (or economic development) theory asserts that free trade is an engine of growth, agriculture serves as backbone to industrialization, and technology (e.g. irrigation, hydropower, etc.) increases factor productivity. This is theoretically consistent with the development path of developed and newly industrialized countries where foreign capital and trade as well as agriculture development and industrialization are central to achieving better standard of living, health and education. Modernization theory recognizes the importance of globalization in raising economic and social wellbeing of society, and thereby, its susceptibility to drought and other extreme climate events. According to a World Bank study (2002), 24 developing countries that increased their integration into the world economy over two decades ending in the late 1990s achieved higher growth in incomes, longer life expectancy and better schooling. Consistent with modernization, a number of less developed and developing countries experienced fall in trade to GDP ratio, which resulted to contraction of economy's output and increase in poverty. A direct connection to susceptibility has been made by research on natural hazards and food security which has confirmed that poverty reduces the capacity of a society to adapt to environmental stress (Blaikie, Cannon et al. 1994; Bohle, Downing et al. 1994).

Dependency theory explains why industrialization and global trade fail to bring about economic growth in developing countries. Industrialization does not develop an urban sector capable of absorbing surplus agricultural labourers, and therefore depresses agricultural wages. Moreover, trade dependency has aggravated the gap between rich and poor countries because of unequal exchange and prices for raw materials and processed products (Shen and Williamson 2001). Countries with low trade revenues were forced to borrow foreign exchange to finance their imports and must use financial resources to repay loans rather than for development projects and welfare programmes, with negative socio-economic consequences. Lack of financial resources result in poor irrigation infrastructure that hinders agricultural development and in weak social services that inhibits social well-being. The former is further aggravated by the fact that hydroelectricity, which is vital to industrialization, competes with irrigation for water supply (Michalland, Parent et al. 1997; Howitt and Sexton 1998). Conversely, Gupta, Verhoeven et al. (2002) show that increased public expenditure on education and health care is associated with improvements in both access to and attainment in schools, and reduces mortality rates for infants and children. However, low-income countries generally invest less in improving social well-being of society. Mundle (1998) points out that it is empirically observed that the ratio of public expenditure to GDP tend to rise with rising per capita income. Finally, the dependency theory argues that women's lives worsened in the process of modernization because their work receives less financial reward and consequently less social value (Bonvillain 2001). However, women have an important role in improving the health condition of society because, more than income (Caldwell 1993), maternal literacy is an important determinant of child survival (Caldwell 1979; 1994).

These various factors and variables are related to each other in the inference model as shown in Figure 3. Results of the inference model (Figures 4 and 7) show that India has the highest level of socio-economic susceptibility in the first half of 1990s. India's susceptibility is highest in terms of financial resources (0.8). As suggested by dependency theory, indicators for education and health show very high susceptibility because India lacks financial resources to support social services. In contrast, Portugal's low level of financial susceptibility is accompanied by very low education and health susceptibility. This is particularly attributed to higher public expenditure on these social services, which is consistent with the concept that policymakers tend to pay more value on human development programmes at a higher level of economic development. The susceptibility of the infrastructure system in India was lowest at 0.3. This could be attributed to the extensive irrigation programme of the government in the past as a measure to promote agricultural development. Notwithstanding this, Indian agriculture remained most susceptible because its labour force continued to be high despite the falling share of the sector to GDP. The infrastructure susceptibility in Russia is mainly attributed to its high dependence on hydropower for energy production, making irrigation only a marginal user of her water resources. Whilst gender susceptibility in Portugal and Russia is low, in India it was maintained at a moderate level. This may be attributed to the influence of India's social structure and cultural values, which encourage women's marginal role in society, which in turn is further aggravated by the impacts of globalization on poverty.

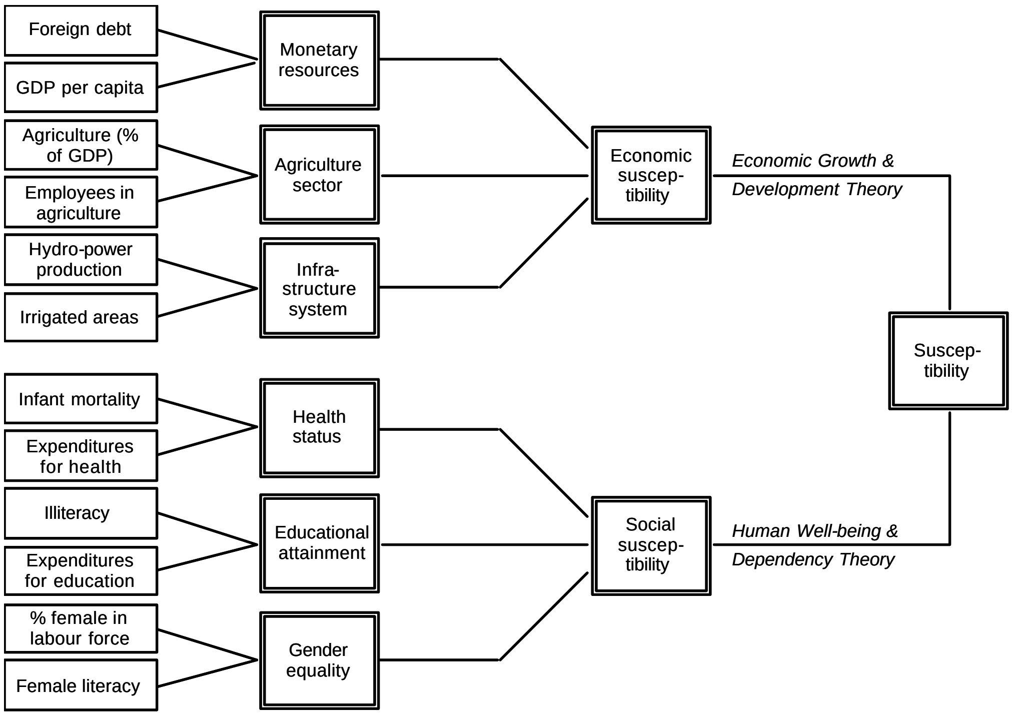

Figure **3.** Conceptual framework for socio-economic susceptibility

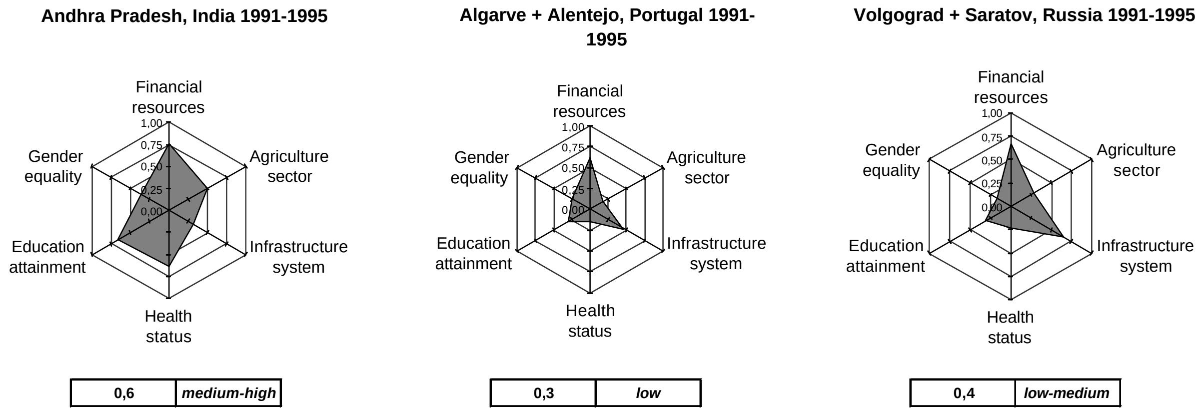

Figure **4.** Cross-country comparison of socio-economic susceptibility, 1991-1995.

3.4 Susceptibility Model from Political Science Perspective

The assessment of a society's susceptibility to environmental stress from a political science perspective focuses on the concept of state capacity. For assessing this capacity we can draw on different approaches to measuring government performance (e.g. Arbetman and Kugler 1997). In addition, other cultural resources such as traditional knowledge, can sometimes compensate for inadequate state capacity (Berkes, 1999). Hence social and economic factors should also be taken into account. To integrate these aspects into a model, we use a systematic approach based on the theory of Parson (1971). In a nutshell, this approach identifies the dimensions of a society crucial to its general functioning and thus to its stability The interplay of political, economic, social and cultural dimensions provides the necessary environment for society to carry out its desired functions such as goal attainment, adaptation, integration and pattern maintenance. In this light, susceptibility means insufficient state capacity to guarantee these desired functions, which in turn means that a certain degree of (environmental) stress will lead to a crisis situation. This approach implies that an inference model of susceptibility from the political perspective must include information on the political, economic, and socio-cultural dimensions of a society.

Political Dimension. A basic assumption of the model is that susceptibility is inversely proportional to the level of state capacity and the willingness of the state to use its capacity to support its population. To estimate the level of state capacity we assume that state capacity decreases when the state is involved in violent conflicts (Jenkins and Bond, 2001) and when state resources such as tax revenue are too low to allow it to respond to crisis. As an indicator of the willingness of the state to support its population, we use the level of support for central social security services such as the health system (WHO, 1981). This “willingness” is decreased by corruption (Lambsdorff, 2001).

Economic Dimension. Two key ideas are used to represent the economic dimension of susceptibility in our model. First, susceptibility is higher for societies with a “lack of wealth” as represented by low income and a large percentage of the workforce in agriculture. This assumption is based on Rössel (2002) who found that the capacity of people is only insufficiently expressed by GDP per capita and that the consideration of the share of work force in the agricultural sector offers a broader picture of the state of regional development. Second, a society is more susceptible to drought if it is economically sensitive to drought. As indicators of this sensitivity we use the extent to which the economy depends on hydropower and domestic agricultural production.

Socio-cultural Dimension. Socio-cultural dimensions are included in the model by hypothesizing that susceptibility is inversely related to the overall degree of social integration in the society (Grindle 1996; Jaggers/Gurr 1995). The lower the level of integration, the higher the susceptibility. We assume that a low level of competitiveness of participation and a low level of immunization rate indicate a low level of social integration.

The various political, economic, and socio-cultural dimensions of our model are related together as depicted in Figure 5.

Figures 6 and 7 shows results of applying the model to the case study regions. The Russian and Indian regions have similarly high levels of susceptibility, while the Portuguese region has a low level. This is mainly due to the higher level of conflict in Russia which decreases state capacity, and higher level of corruption in India which decreases state “willingness”. The computed trend since the 1980s shows a large decrease in susceptibility in Portugal because of positive changes in almost all factors taken into account by the model. Smaller improvements were computed for the Indian and Russian regions.

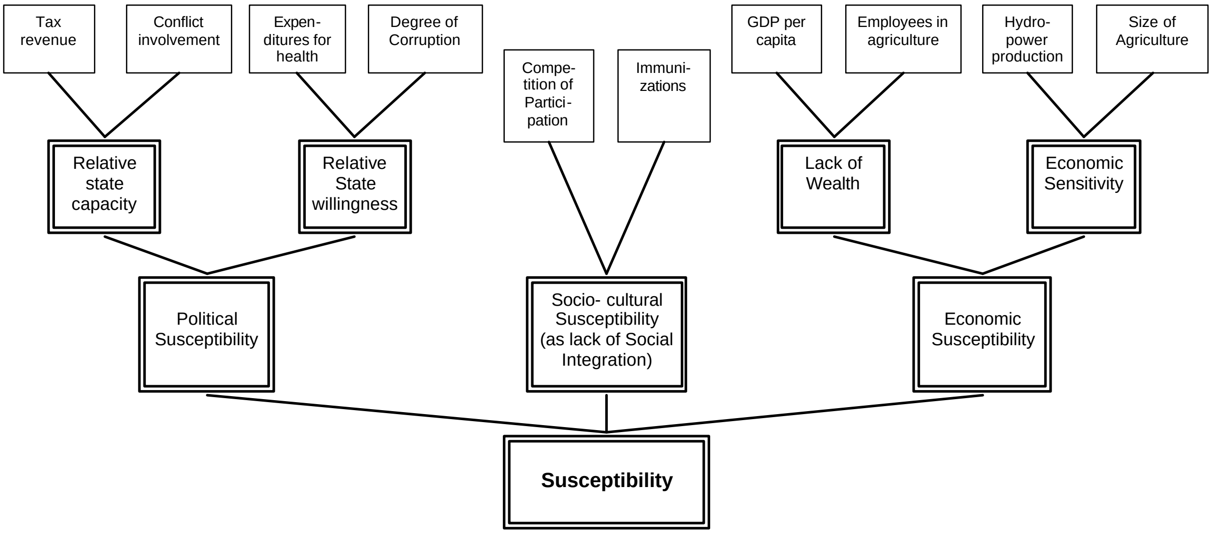

Figure **5.** The concept of Susceptibility from a political science perspective

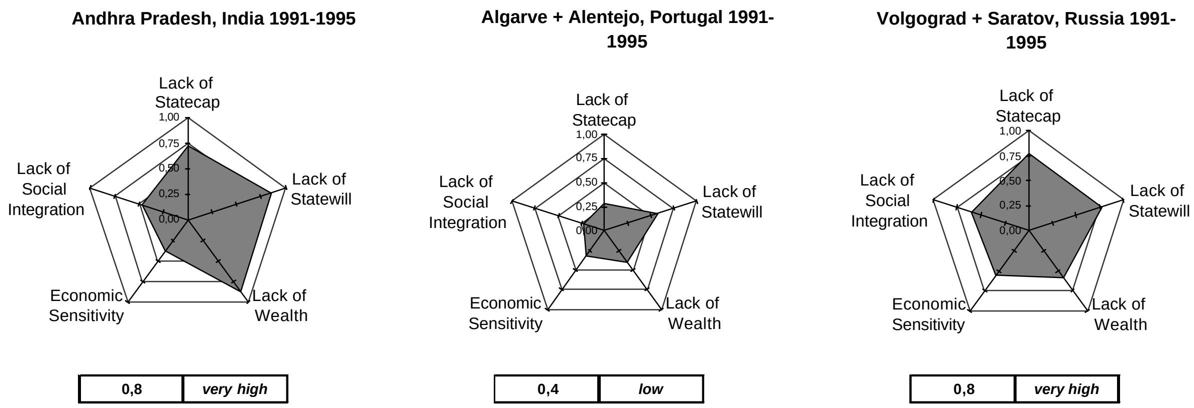

Figure **6.** Influence factors of susceptibility from political science perspective.

3.5 Comparing Results from 3 Susceptibility Models

Figure 7 summarizes the estimates of susceptibility for the case study regions using the three different disciplinary models with measured data from the regions. This is perhaps the first attempt to compare quantitative estimates of susceptibility to drought from three different disciplinary perspectives. Using the methodology described above, we have created a consistent basis for comparing differences between perspectives, and for identifying the importance of differences.

An interesting result was that the three perspectives computed very close quantitative estimates for the susceptibility of the Portuguese region (0.26 to 0.36). This could be because our method is insensitive to the question of susceptibility in industrialized countries. Another more interesting alternative is that the similarity in estimates indicate that a wide range of disciplinary perspectives give a similar susceptibility rating for richer countries. This must be tested by applying the approach to a variety of industrialized regions.

There was another interesting similarity between perspectives – The psychology and economics perspectives estimated the Russian and Portuguese regions have about the same susceptibility, although we had expected that the Russian region would be more susceptible because of the difficult socio-economic transition it is undergoing. Despite this transition, the psychology model estimates that susceptibility is relatively low in Russia because individuals and communities have a relatively high level of resourcefulness in the face of droughts and other crises. This more than compensates for other factors in the psychology model that tend to increase susceptibility. In the economics model the Russian region received relatively high scores for education and gender equity, and the model assumes that these tend to produce a low susceptibility. The political model, however, computes a much higher susceptibility for the Russian region because of the high score it receives for "conflict involvement" and the "degree of corruption" which are assumed to contribute to susceptibility.

All three disciplinary perspectives assign Andhra Pradesh in India the highest susceptibility of the three case study regions, although absolute values ranged from 0.58 to 0.79. The lowest value was estimated by the economics perspective, partly because it assumed that the region's dependence on irrigated agriculture serves as a hedge against drought. Of course having a large agricultural areas dependent on irrigation can also be viewed as a large exposure to drought.

How can knowledge from the three perspectives be integrated into a comprehensive model of susceptibility? The psychological perspective suggests that we should include indicators that capture the ability of individuals and communities to be creative and resourceful in mitigating the impacts of droughts. From the political perspective, we are reminded that political stability is an important factor to include in a general susceptibility model. From the economics perspective we learn that access to infrastructure and gender equity may play important roles in overall susceptibility.

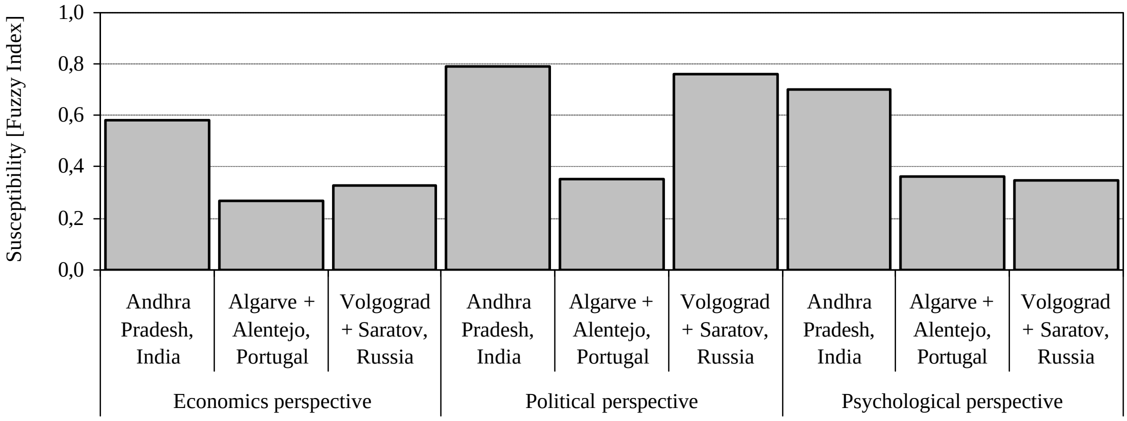

Figure **7.** Comparison of the different perspectives on susceptibility.

4. Results – The Challenge of Validating Vulnerability Estimates – The Option of Crisis Data

Although scientists have invested huge effort in estimating vulnerability to drought and other climate events, this effort has been hampered by their inability to validate these estimates. Scientists can estimate whether one region versus another is more susceptible or is more exposed to higher water stress, but cannot say whether this will lead to negative impacts. When is the level of susceptibility or water stress high enough to cause concern? The main problem with validating estimates of susceptibility and water stress is that these concepts are related to complicated societal processes and therefore the concept used for validating them should also incorporate these processes. In this project we have experimented with using the occurrence of “drought-related crisis” as an independent variable for testing vulnerability estimates. (For our working definition of crisis see Footnote 1). The concept of drought-related crisis as we use it here implies that water stress is high enough that it causes negative consequences to society. To this end we have compiled a crisis data base for our case study regions and in Section 5 use these data to test different indicators of water stress and their thresholds.

We have compiled crisis data by carrying out a media analysis using key words to identify the occurrence of crises. Our source of information is the Factiva data base which summarizes key words for over 8000 media sources around the world dating back to 1980. Since Factiva covers local media sources including those in our case study regions, it provides a unique opportunity to identify the extent of media coverage of droughts during the study period of this project. Some years had intensive coverage compared to other years, and for these years we analysed media reports more closely to confirm the “attributes” of the crisis – For example in some years the media reported significant cutbacks in hydroelectric production, curtailment of drinking supply, the distribution of aid, and other impacts and actions. This increased our confidence that the drought was severe enough to put in the category of “crisis”. We also compared results of the media analysis with further information about reported impacts from local surveys. We sum up this information in Table 1 which shows the years in which we estimate that drought-related crisis occurred in the case study regions (Taenzler and Feil, 2003).

Of course, these data do not indicate the intensity of crisis, but we believe that our media analysis does not justify such distinctions. Nevertheless, the data in Table 1 provide perhaps for the first time, an independent basis for testing vulnerability indicators. We use these data to test water stress indicators in the next section.

Table 1. Drought induced crisis events in the case study regions 1980 to 1999 based on findings of media analysis and other material. See Taenzler and Feil (2003).

Year 19	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
India									X					X				X	X	
Portugal		X											X			X				X
Russia																X		X	X	

5. Results – Testing and Identifying Thresholds of Water Stress With Crisis Data

Water stress is a useful concept for assessing the impacts of water scarcity on society. Several indicators have been used to measure water stress, but their use and thresholds have been supported mostly by expert judgement rather than scientific evidence. Therefore it is particularly interesting to use the crisis data set described above as an opportunity to independently test different water stress indicators. We first compute 14 different water stress indicators (see Table 2) for the case study regions using the WaterGAP model (Alcamo, et al. 2003a, b). The WaterGAP model computes many different hydrological and water use data for the case study regions, and these data are used to construct the 14 indicators. Using a model rather than observed data helps to fill in the large gaps in local data and provides a consistent framework for comparing the results from the three case study regions. Table 2 shows which indicators found to have a statistically significant relationship to the occurrence of drought-related crisis from 1980 to 1995 taking into account all case study regions (t-test with 0.95 significance level).

After analyzing the results more closely we noticed that some indicators are clearly not appropriate for particular types of watershed areas.[2] We therefore propose a new indicator which is the maximum function ("MaxIndex") of three other indicators (see Table 2). This aggregate indicator shows a higher statistical significance than any of the single indicators, and seems to be applicable to a wider range of watershed areas.

Table 2. Results of t-tests for the occurrence of crises and different water stress indicators.

Statistically significant indicators	Not statistically significant indicators
▪ Water withdrawal to availability ratio ▪ Deviation of groundwater recharge from long time average ▪ Deviation of water availability from long time average ▪ Runoff deficit index ▪ Deviation of evapotranspiration from long time average ▪ MaxIndex (maximum function of water withdrawal to availability ratio, deviation of water availability from long term average, and percentage of area with high water stress (defined as water withdrawal to availability ratio of 0.4 or higher).	▪ Water withdrawal to internal availability ratio ▪ Annual groundwater recharge in mm ▪ Groundwater discharge per capita ▪ Water availability per capita ▪ Internal renewable water availability per capita ▪ Percentage of area under stress (defined as withdrawal to availability ratio of 0.4 or more) ▪ Percentage of population under stress (population in areas under stress defined as withdrawal to availability ratio of 0.4 or more) ▪ Deviation of precipitation from long time average

Different computed values of the MaxIndex are compared to the occurrence of drought-related crises from the study regions in Figure 8 and interestingly show that the occurrence of crisis steadily increases as values of this index increase, and crises seldom occur when the value of this index is below 0.4.

These results must be taken as preliminary because they are based on a small data set from only 3 regions, and because it relies on the somewhat subjective concept of drought-related crises. Nevertheless, considering the diversity of regions that are covered by these results, this seems to be a promising method for testing water stress indicators and identifying their thresholds.

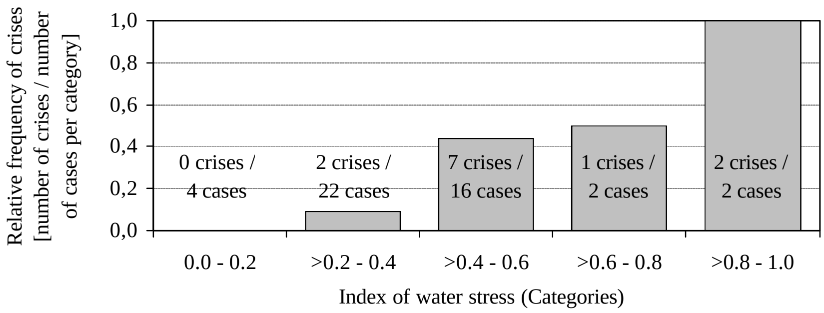

Figure **8.** Relation between MaxIndex indicator of water stress and relative frequency of crises events.

[2] For example, since much of the water in the Volgograd-Saratov region comes from outside with the large flow of the lower Volga, the indicator "withdrawals to availability ratio" will always indicate that the level of water stress is low (because the Volga always provides a source of water for those that live near it). This however underestimates the impact on drought on inhabitants that live too far from the Volga to exploit its waters during a drought. For these inhabitants, a better indicator of water stress would be, for example, the percentage of area in the region experiencing high water stress.

6. Discussion and Main Conclusions

In Section 3.1 we elaborated a new methodology for quantifying susceptibility from different disciplinary viewpoints. This new methodology is flexible and easy to carry-out and has potentially wide applications outside of this project for quantitatively estimating the susceptibility of a population to drought and other extreme climate events.

Although the models of susceptibility in Sections 3.2 to 3.4 have some theoretical basis, there is still a measure of subjectivity in how we specified the relationships between variables and the weighting of importance of different variables. Therefore an important research task is to empirically test the models with statistical analyses of data from case study regions to confirm the relationships assumed in the models. With these qualifications in mind, these models nevertheless provide examples of how different disciplinary viewpoints can be successfully represented in inference models.

In Section 3.5 we made a first comparison of susceptibility estimates from different disciplinary perspectives. The three perspectives all estimate low susceptibility for the Portuguese region. But surprisingly, the economics and psychology perspectives both estimate the susceptibility of the Russian region to be about the same as the Portuguese region because of particular factors that they take into account. This comparison is just the beginning of a major task to synthesize insights from different perspectives into a comprehensive concept of vulnerability.

Meanwhile, the crisis data set described in Section 4 and its application to water stress indicators in Section 4 is promising as an approach for independently testing vulnerability estimates. Yet a much wider range of regions must be examined.

6. Planned activities

We propose to carry out Phase 2 of this project under the title “Security Diagrams – A New Approach to Rapid Assessment of Vulnerability to Climate Change”. In this new phase we will develop a methodology for rapid assessment of the vulnerability of a region to climate change. By “rapid assessment” we mean an assessment carried out over a period of one to two years using a structured procedure that relies mainly on existing data (with the collection of a limited amount of new data). By “region” we mean a geographic part of a country having some unifying feature (comprised of a single river basin, a similar economic or climate system, etc.). We will test the Rapid Assessment methodology on real world data from 4-5 additional case study regions. The final step in our approach will be to communicate the new methodology to potential users in the form of workshops, short courses, and internet tutorials.

7. Cooperation within DEKLIM and with other programs

We plan to cooperate with the following other research projects in the phase 2 of the Security Diagrams project in order to carry out case studies with our new developed methodology:

- Deklim-C project IMPENSO. The Deklim C Project IMPENSO investigates the impact of climate change on society and focuses on water scarcity. This project uses a multi disciplinary approach that includes a bottom-up perspective and works with survey techniques as our Security Diagrams project as well. These are very good conditions for a project cooperation and a use of our Security Diagram methodology for the Central Sulawesi case study region.
- DFG Sonderforschungsbereich 552 "Stability of Rain Forest Margins in Indonesia" STORMA, Sulawesi, subproject D5. One of the principal aims of the STORMA

subproject D5 is to build Integrated Land Use Model of the forest margin area of Central Sulawesi. One of the main objectives of this model is to integrate many of the socio-economic and natural science aspects of different STORMA projects. Our Security Diagrams method and the new rapid assessment method to quantify vulnerability to climate change would be a promising enrichment of this integrated model.

- GLOWA-Danube – German Danube region. Principal aim of the project is the development and utilization of the integrated decision support system DANUBIA to investigate ways of sustainable future water use. The psychology research group, coordinated by Prof. Dr. A. Ernst, Kassel analyses households in order to identify the factors that most influence water use.

7. Policy relevance and application

The methodology developed in this project for quantifying susceptibility can be used to identify the major factors leading to susceptibility of a region to droughts. This information can provide concrete input to policies for increasing the adaptive capacity of the region.

Furthermore, the methodology provides a powerful way to include not only expert knowledge, but also local knowledge, into a vulnerability assessment. Hence it provides a way to involve and actively engage stakeholders in vulnerability assessments.

The new "MaxIndex" indicator can serve as a useful policy tool for evaluating the level of water stress in different parts of a country or region, and can provide input to water resource planning projects.

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