APPENDIX

National vulnerabilities over time

The vulnerability-resilience indicators are calculated from a hierarchically designed combination of national and global information in our Vulnerability-Resilience Indicator Prototype (VRIP) model. Proxies representing potential response indicators to change are composed of national or global data and indexed against a standard, represented by the world baseline data of 1990. The proxies are aggregated into sectoral indicator by calculating their geometric means. The sectoral indicators are then integrated into indicators for sensitivity (S) to climate impact or for coping and adaptive (CA) capacity by calculating their geometric means. The arithmetic difference between the coping-adaptive capacity as a positive value and sensitivity as a negative value becomes the value of the vulnerability-resilience (VR) indicator.

The indicators are projected into the future by projecting each of the proxies into the future, indexing them against the world baseline data, and calculating the aggregated indicators at 15 year time intervals. Information for the projections is obtained from outputs from the integrated assessment model MiniCAM (Edmonds et al. 1997) and its postprocessor Sustain (Pitcher, 1997). These models project economic change, land use change, changes in demographics, food needs and the environment in 11 regions of the world.

Figures A1-A12 show the changes over time in three scenarios of the sensitivity, the vulnerability-resilience, and the coping-adaptive capacity indicators. The A1v2 scenario represents a rapid growth scenario; the B2h scenario represents local sustainability; the A2A1 scenario represents delayed development.

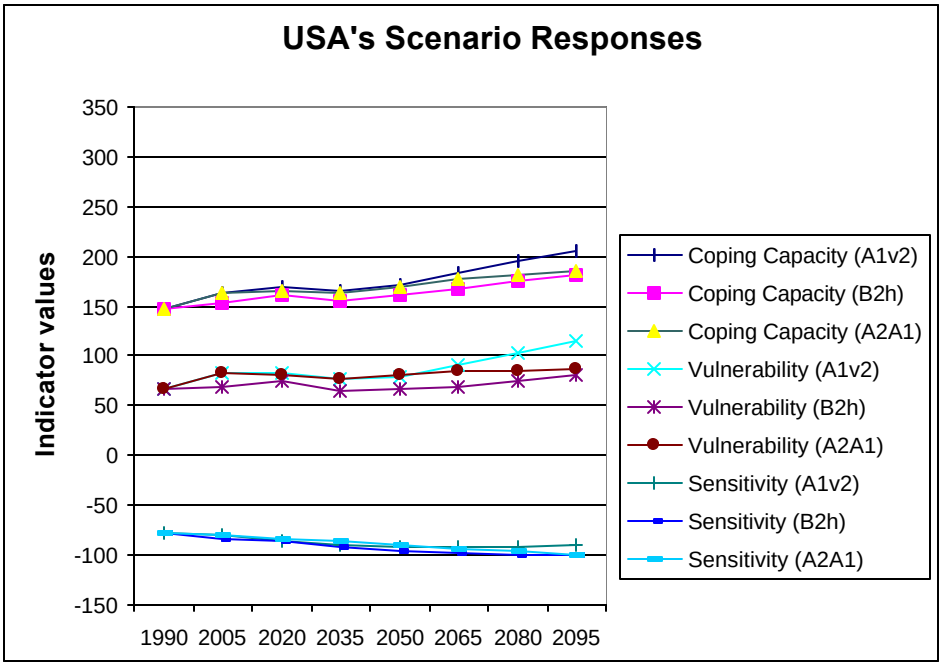

Figure A- 1 USA's indicator values over time (MiniCAM region 1)

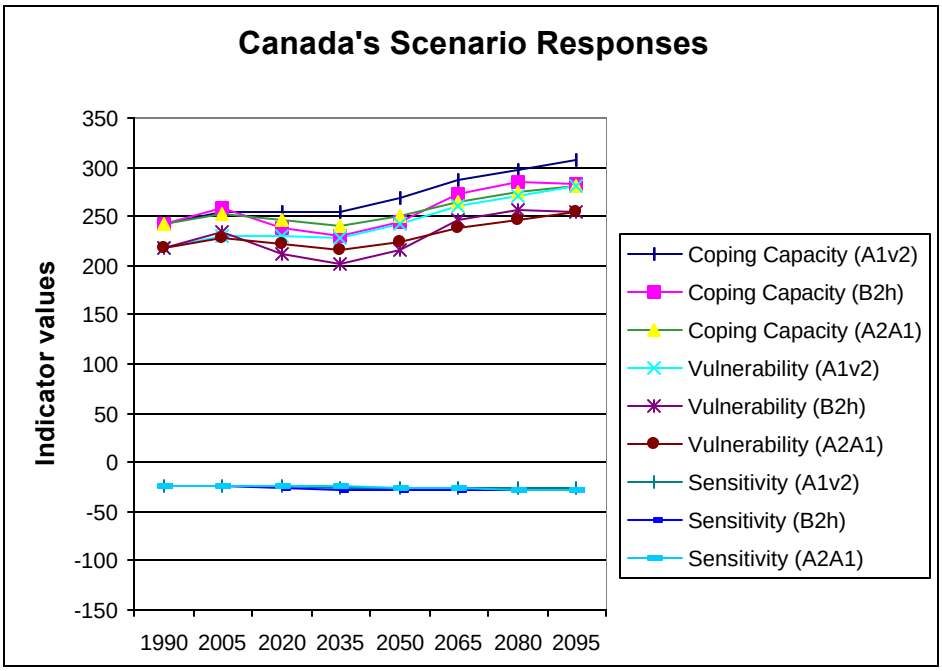

Figure A- 2 Canada's indicator values over time (MiniCAM region 2)

The United States and Canada's vulnerability-resilience indicators differ, with the United States showing less resilience compared to Canada due to a lower indicator value for coping and adaptive capacity and a greater sensitivity, especially as projected into the future. When discussing the decomposition of these indicators into sector and proxy contributions, in the next sections, we will find some explanations for these differences.

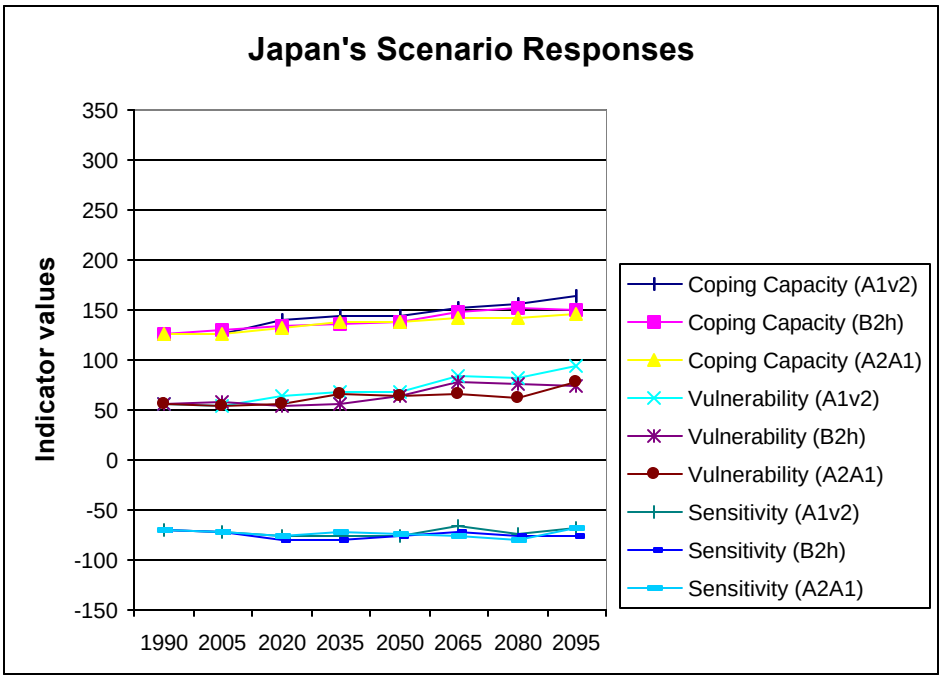

Figure A- 3 Japan's indicator values over time (MiniCAM region 4)

Japan and Spain (Figure 15 in the main body text) show very similar indicator values over time and a similar balance between sensitivities and coping and adaptive capacities, although Spain's sensitivities are increasing more over time compared to Japan's and after 2065 we find more divergence among Spain's scenario projections.

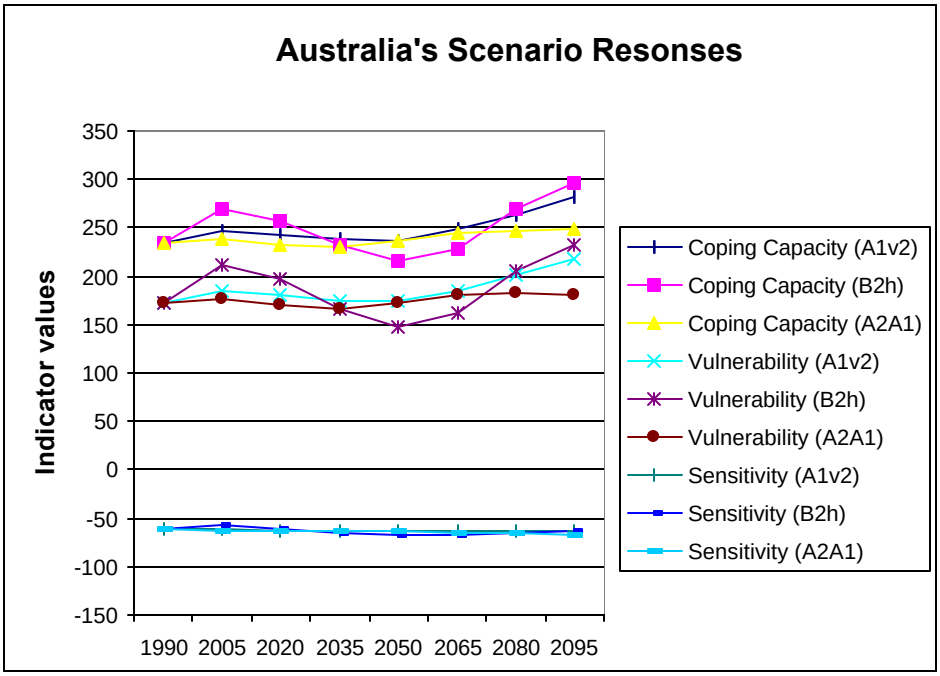

Figure A- 4 Australia's indicator values over time (MiniCAM region 5)

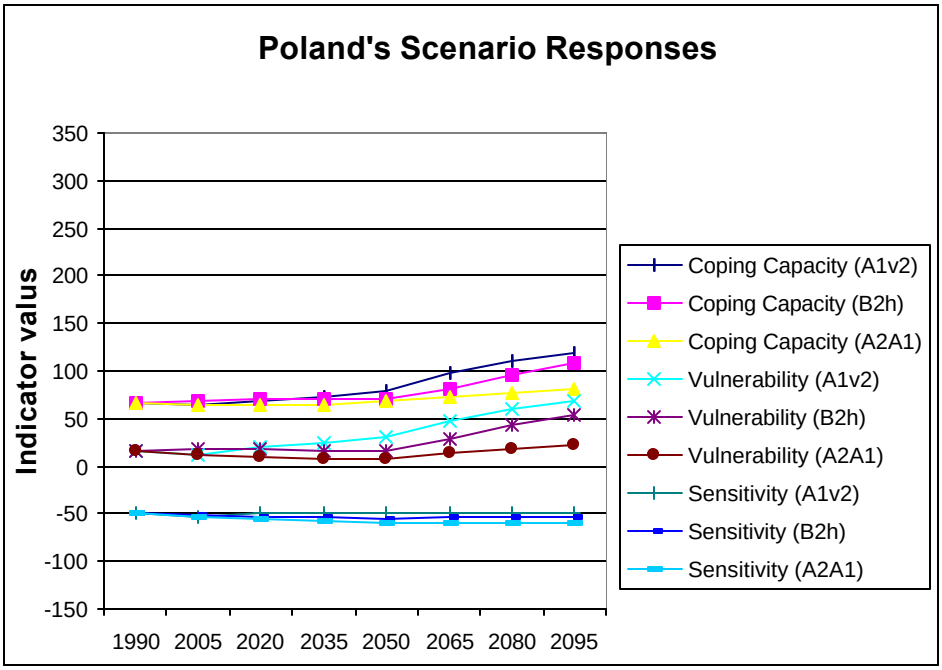

Figure A- 5 Poland's indicator values over time (MiniCAM region 6)

While Spain and Japan's vulnerability-resilience indicators ranged roughly between 50 and 100 over time, Australia's VRI ranges between 150 and 250, showing Australia as much more

resilient due to its high coping and adaptive capacity. Poland and Austalia show similar values for their sensitivity but the coping and adaptive capacity in Poland is considerably lower, albeit, significantly increasing over time, but still resulting in lower resilience compared to Spain's, Japan's and Australia.

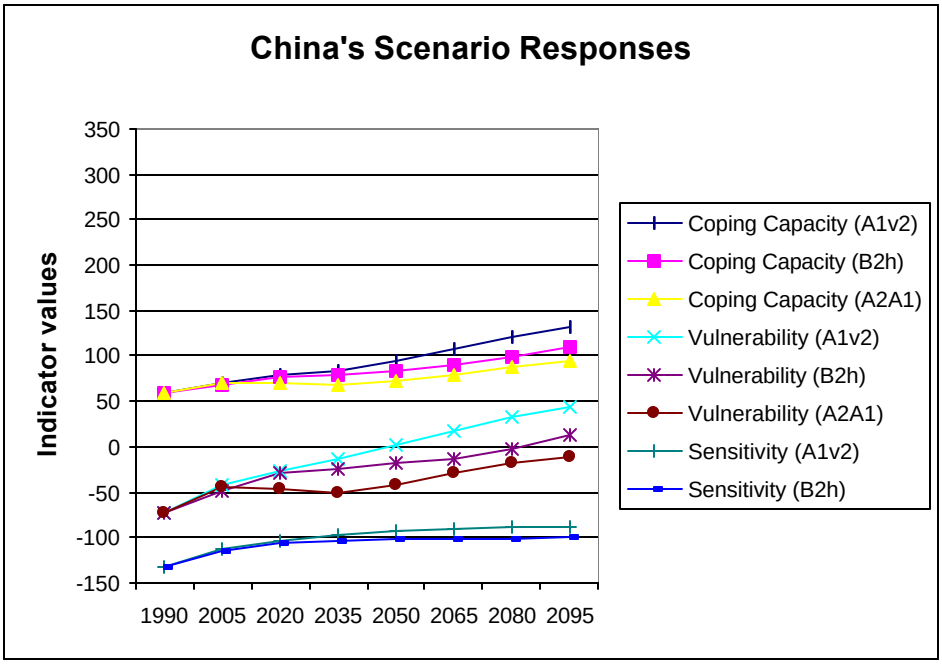

Figure A- 6 China's indicator values over time (MiniCAM region 7)

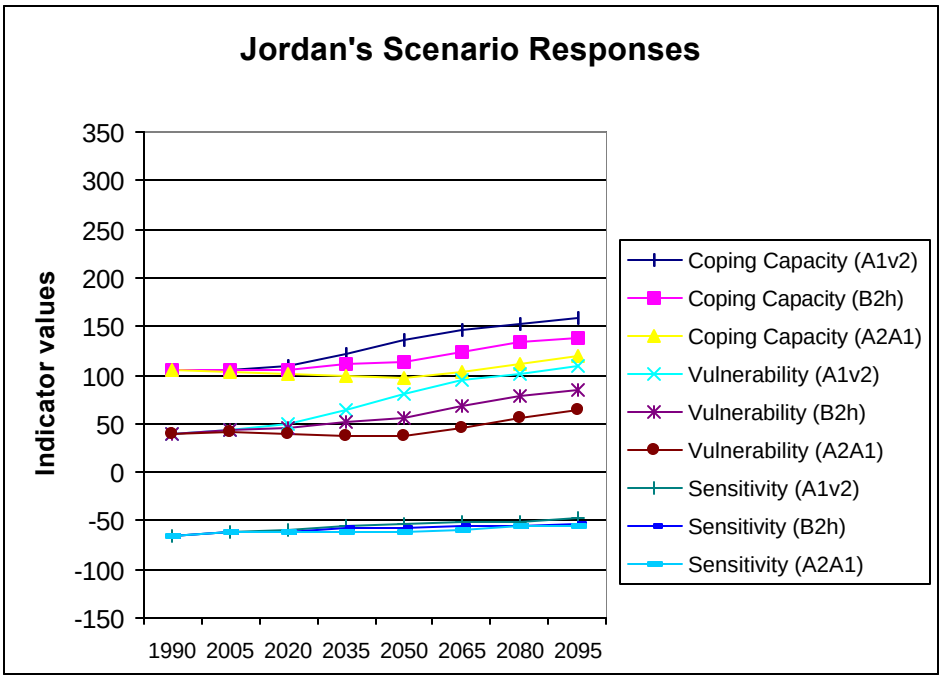

Figure A- 7 Jordan's indicator values over time (MiniCAM region 8)

China's sensitivity to climate change is high but projected as decreasing over time. China's coping and adaptive capacity is comparable to Poland's around the year 1990 and increasing over time in a similar fashion. Its resulting vulnerability is considerable higher, but significantly

decreasing over time especially in the rapid growth scenario after year 2050. Due to Jordan's relatively high coping and adaptive capacity it shows increasing resilience over time.

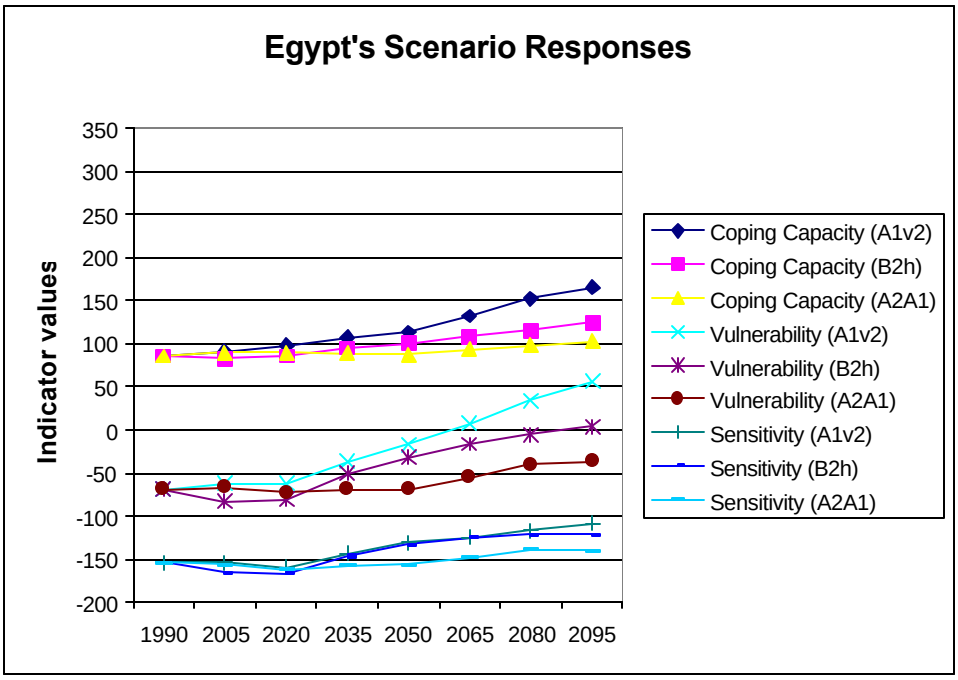

Figure A- 8 Egypt's indicator values over time (MiniCAM region 9)

Vulnerability is high both in Senegal (Figure 16 main body) and Egypt, as was also shown for China. For Africa, high regional economic growth is projected for all three scenarios resulting in resilience by the year 2050 for the rapid growth scenario and by the year 2065 for the local sustainability scenario. We will see later different proxies playing a dominant role in contributing to Senegal and Egypt's vulnerability-resilience indicator values.

We noted in the main body of this report that different countries belonging to the same MiniCAM region and having their baseline values projected through the same percentage changes over time show country-specific balances among the proxies and indicators, resulting in their unique vulnerability-resilience indicator values over time. Brazil and Mexico show this.

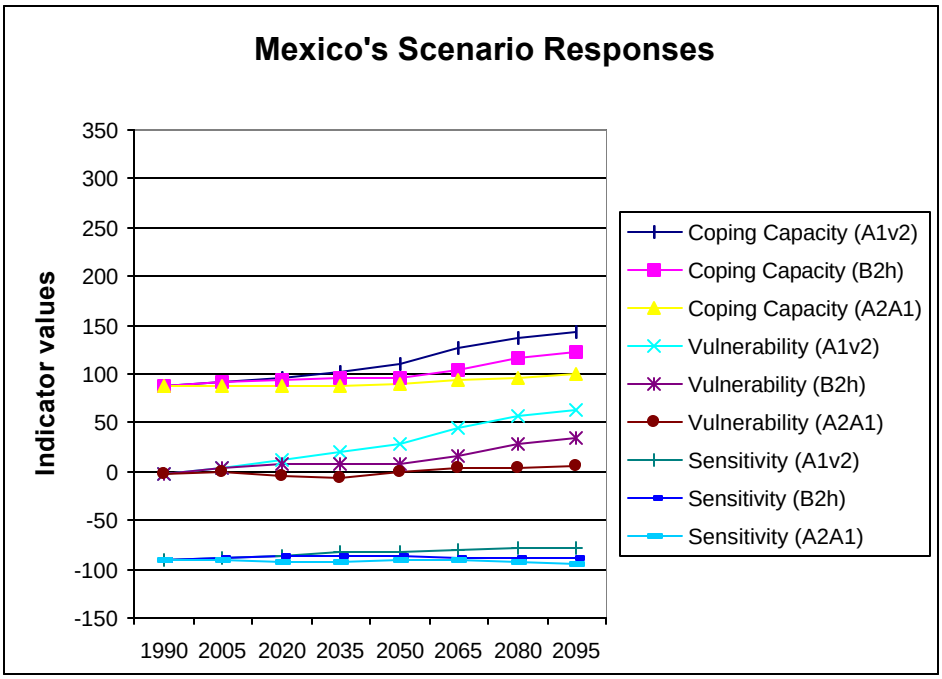

Figure A- 9 Mexico's indicator values over time (MiniCAM region 10)
Bangladesh, India, and Thailand are three countries from MiniCAM's South-East Asia region. Bangladesh shows resilience only after 2065in the rapid growth scenario, while India shows resilience for all three scenarios after 2065, Thailand after 2005.

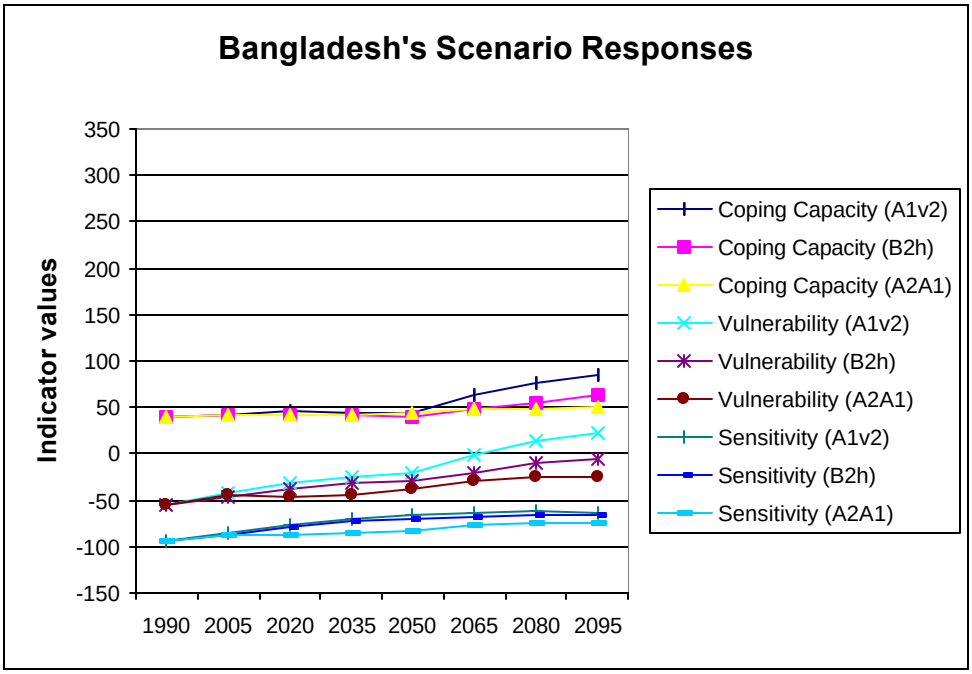

Figure A- 10 Bangladesh's indicator values over time (MiniCAM region 11)

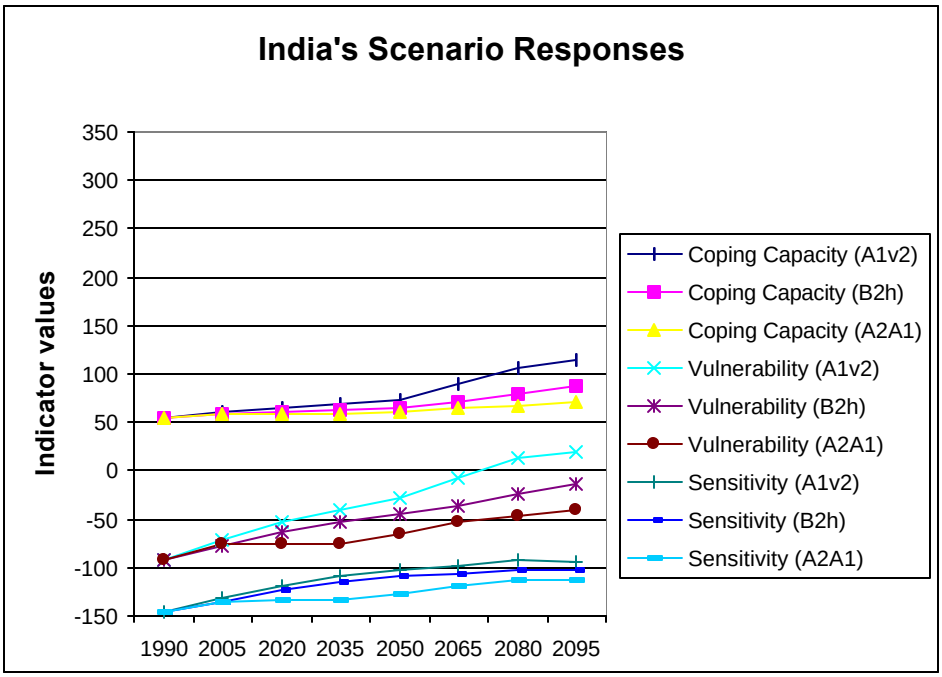

Figure A- 11 India's indicator values over time (MiniCAM region 11)

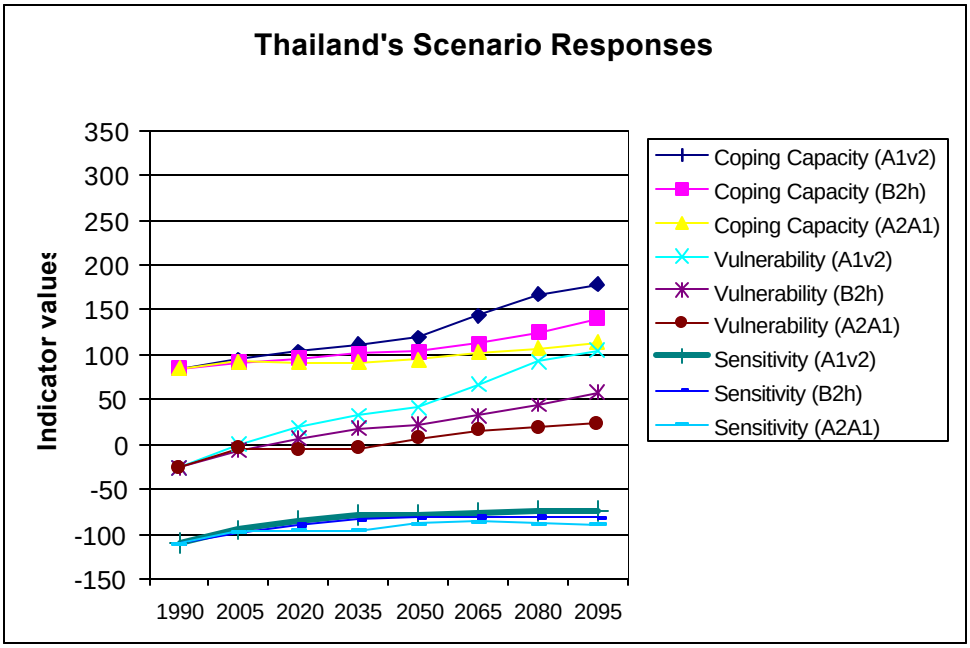

Figure A- 12 Thailand's indicator values over time (MiniCAM region 11)

Vulnerability Decomposed into Sectors

The rapid growth scenario and the delayed development scenario differ mostly in the economic capacity sector, and for the delayed development scenario seemingly at the cost of ecosystem sensitivity. Water sensitivity is similar in both scenarios

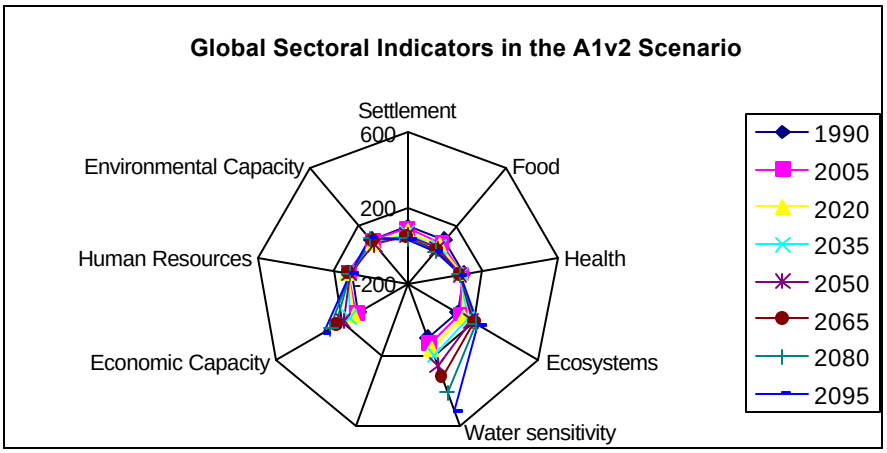

Figure A- 13 Global sectoral indicators in the rapid growth scenario

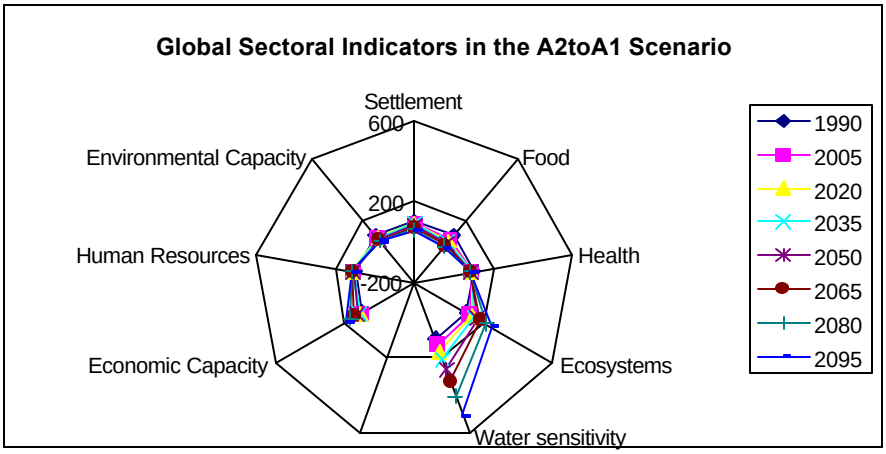

Figure A- 14 Global sectoral indicators in the delayed development scenario

The United States and Canada's sectoral indicator values are quite different and consequently weigh differently against each other, which explains the noted differences in their vulnerability-resilience indicators. Water sensitivity is the dominant indicator in the USA's case. Water sensitivity is projected as increasing over time, which explains the increasing overall sensitivity. Canada's large environmental capacity explains its present and future coping and adaptive capacity.

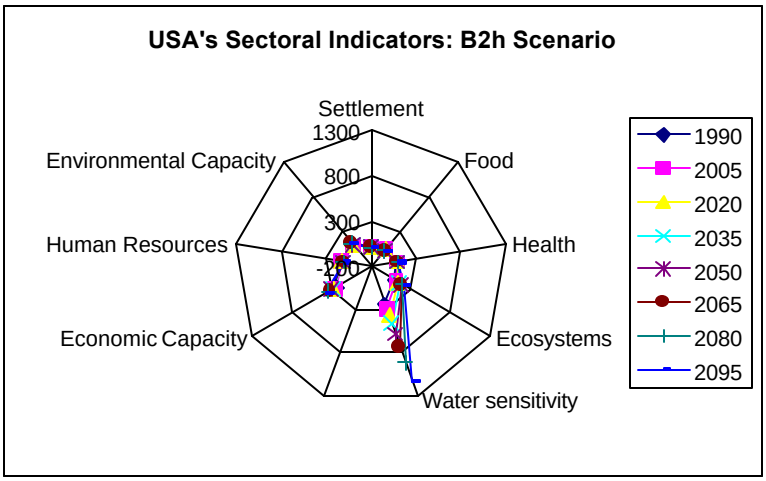

Figure A- 15 USA sectoral indicators in the delayed development scenario

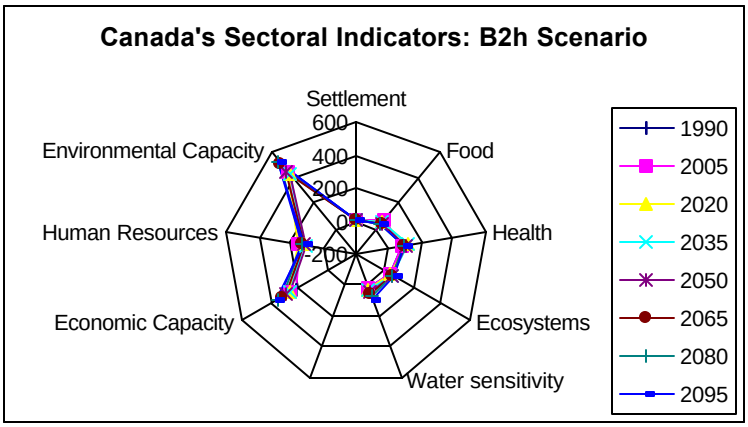

Figure A- 16 Canada's sectoral indicators in the delayed development scenario

As for the United States, water sensitivity is the dominant sensitivity indicator for Spain and Japan. For Spain this sensitivity is projected as increasing more than for Japan, resulting in a greater overall sensitivity

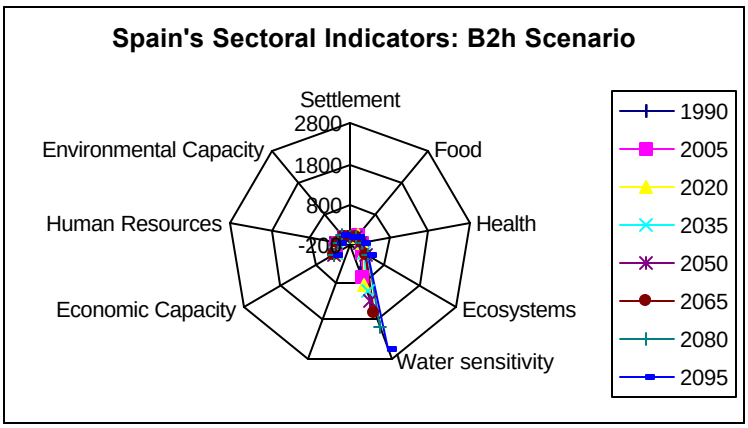

Figure A- 17 Spain's sectoral indicators in the delayed development scenario

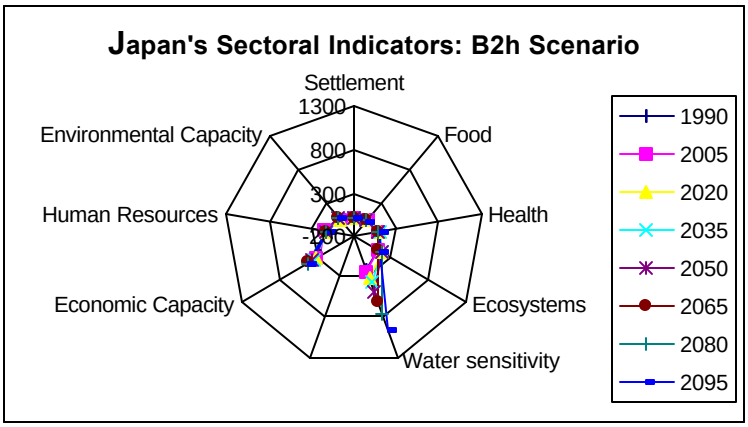

Figure A- 18 Japan's sectoral indicators in the delayed development scenario

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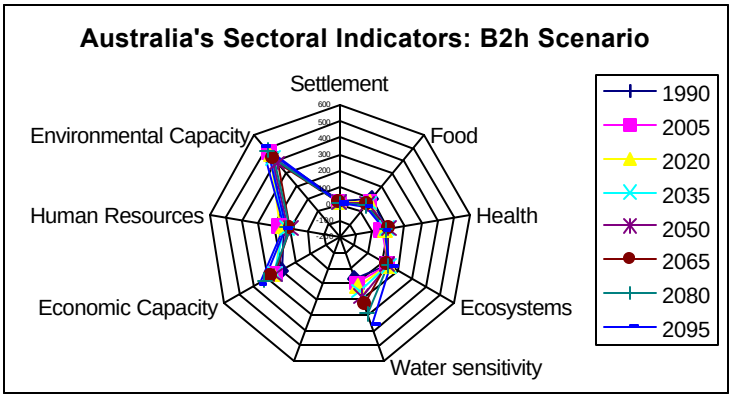

Figure A- 19 Australia sectoral indicators in the delayed development scenario

Australia, like Canada, shows a large environmental capacity and not as large a water sensitivity as some of the other countries, albeit that the water sensitivity is projected as increasing over time.

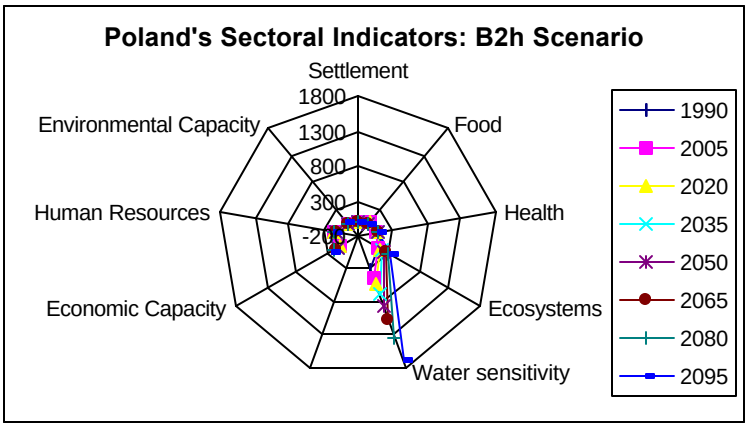

Figure A- 20 Poland sectoral indicators in the delayed development scenario

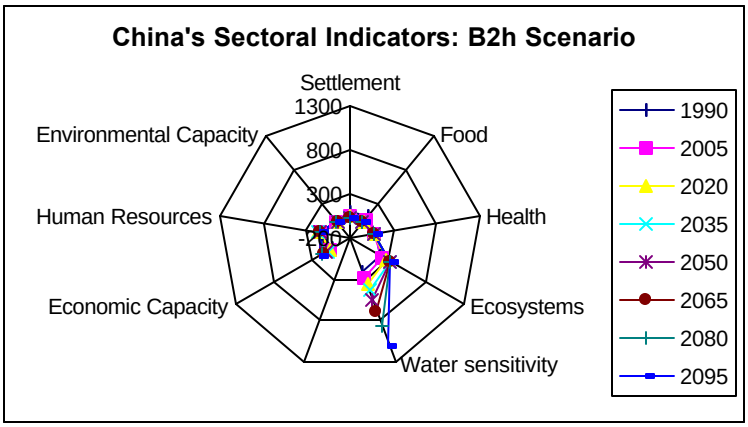

Figure A- 21 China's sectoral indicators in the delayed development scenario

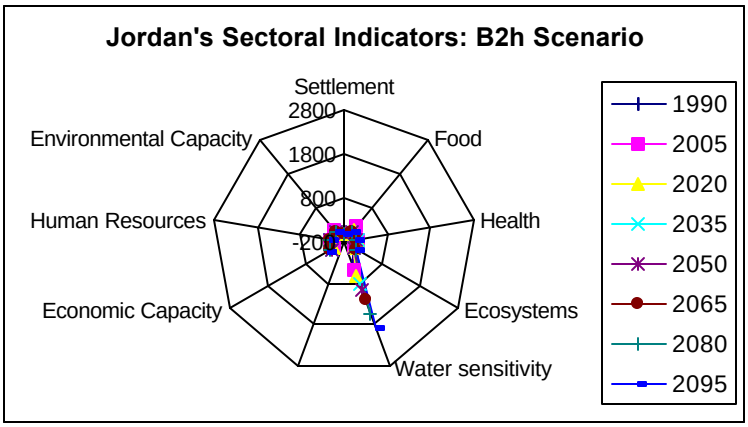

Figure A- 22 Jordan's sectoral indicators in the delayed development scenario

Poland's, China's and Jordan's water sensitivities are the dominating indicators, swamping out most of the other indicator information. China and Poland show in 1990 definite ecosystem sensitivity that is projected as increasing over time in a similar fashion

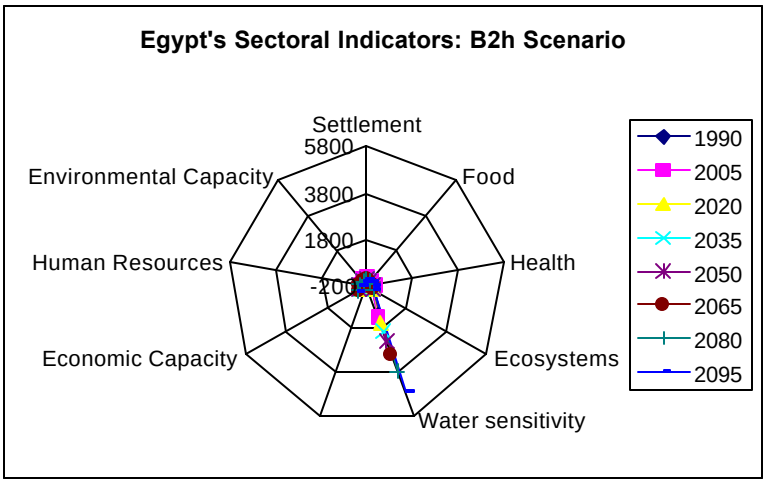

Figure A- 23 Egypt's sectoral indicators in the delayed development scenario

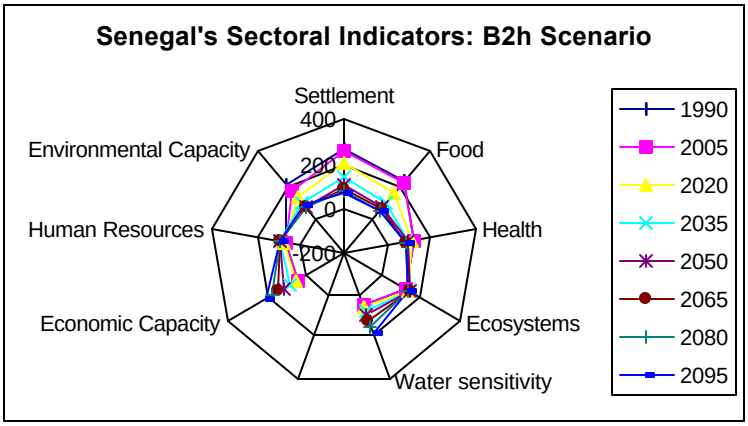

Figure A- 24 Senegal's sectoral indicators in the delayed development scenario

For Senegal as a nation, water sensitivity is not the dominating indicator. This type of result shows, though, that subnational indicators might be more relevant. The northern part of Senegal, as part of the Sahel is definitely water sensitive. Senegal shows significant settlement sensitivity based on the risk of the population to sea level rise in its coastal area, which, of course is not immediately relevant to the dry uplands of Senegal. One may still want to argue, however, that national policy makers need knowledge about all potential sensitivities and coping and adaptive capacities on a national level.

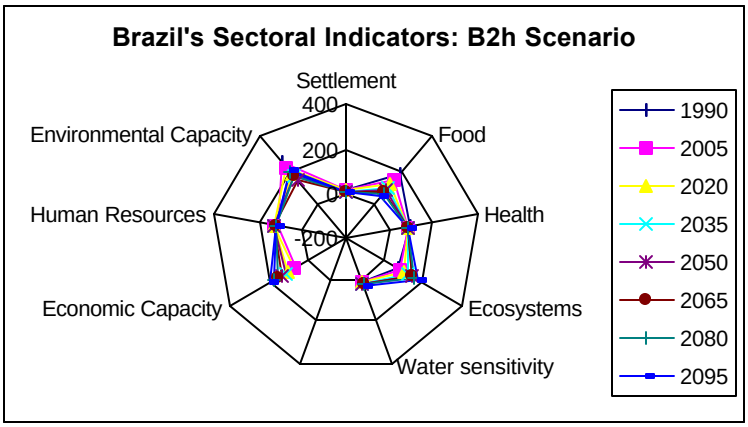

Figure A- 25 Brazil's sectoral indicators in the delayed development scenario

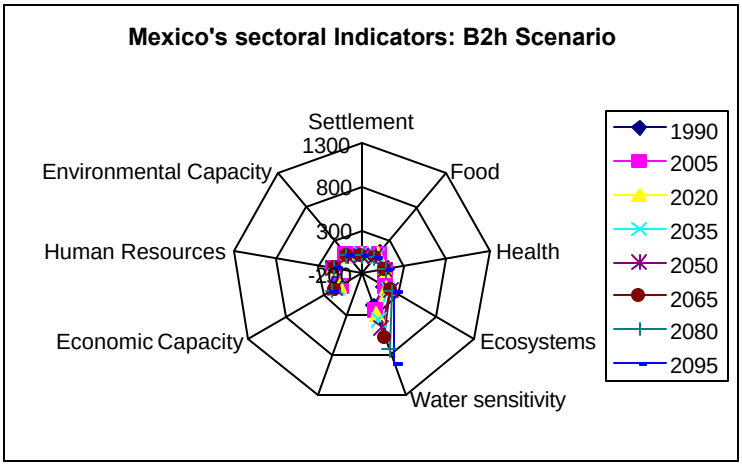

Figure A- 26 Mexico's sectoral indicators in the delayed development scenario

Brazil and Mexico differ significantly in their decomposition of the vulnerability-resilience indicator into their contributing sectoral indicators. For Mexico water sensitivity is dominant. For Brazil, however, water availability does not show as important. In the main body of the report we discuss this.

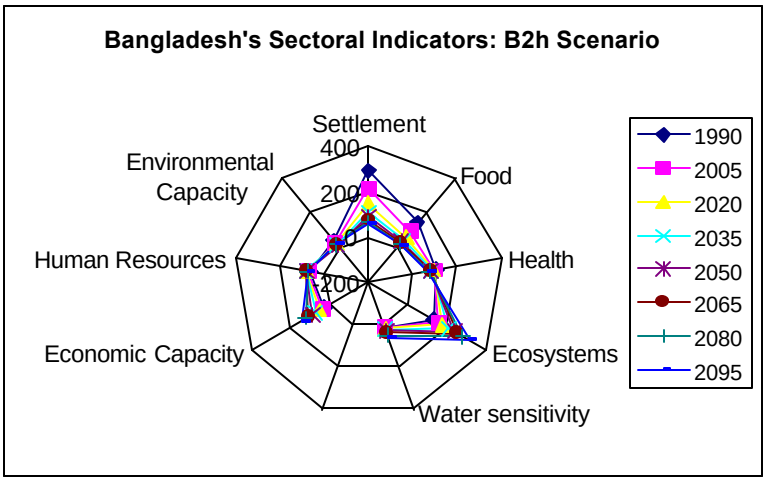

Figure A- 27 Bangladesh's sectoral indicators in the delayed development scenario

Bangladesh differs from India's and Thailand's in its apparent large ecosystem sensitivity. Its settlement sensitivity is due to the combination of non-access to clean water and sanitation by the population and the risk due to sea level rise.

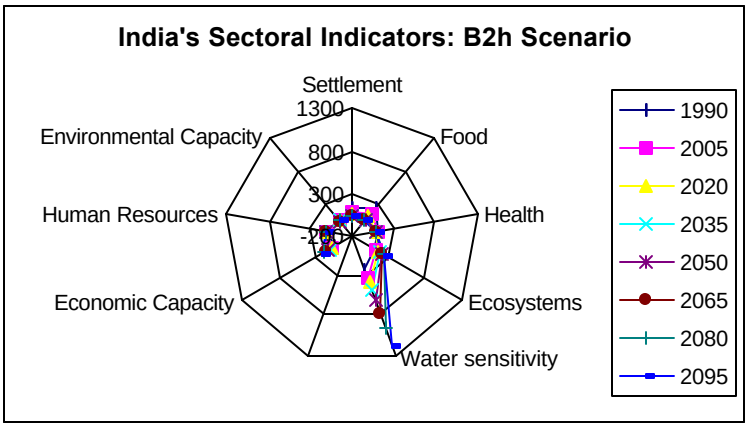

Figure A- 28 India's sectoral indicators in the delayed development scenario

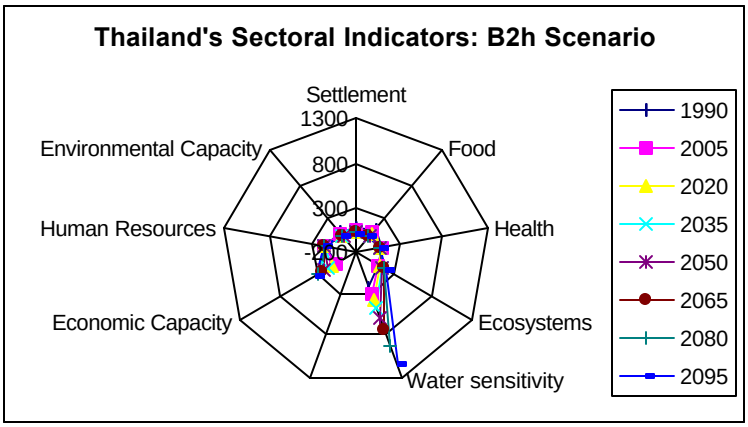

Figure A- 29 Thailand's sectoral indicators in the delayed development scenario

The water sensitivity indicator seems dominant in eleven out of the sixteen countries. If water sensitivity would incorporate electricity generating hydropower, industrial water use, agricultural water use and household water use, besides the general ratio general water use versus available river water that we use presently, and if we would use different sets of projectors besides agricultural water use, a different water sensitivity might emerge.

Vulnerability Decomposed into Proxies

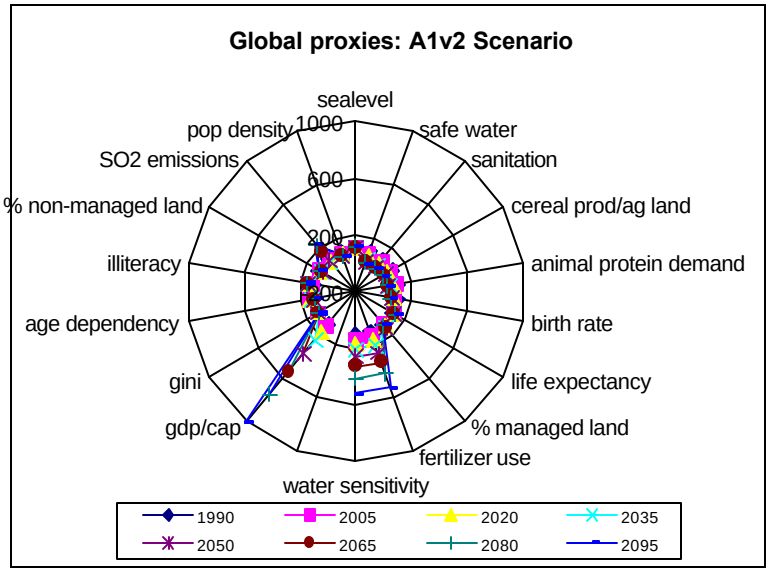

Figure A- 30 The global proxies in the rapid growth scenario

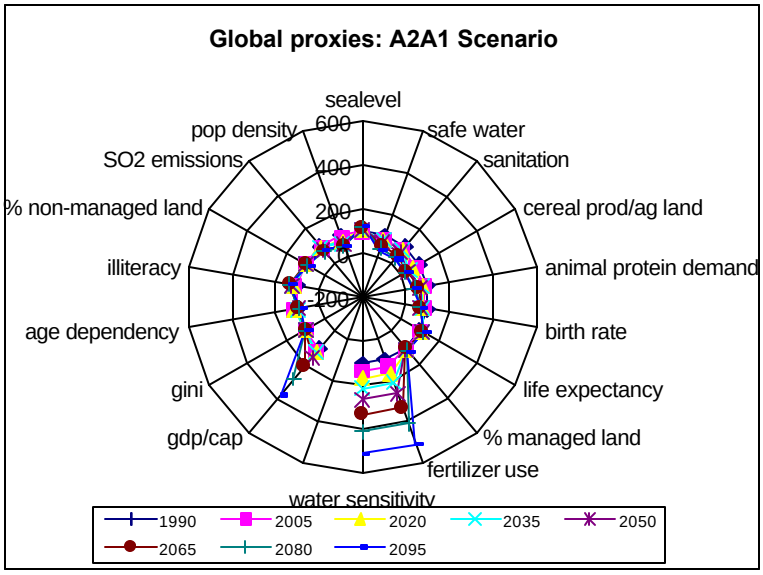

Figure A- 31 The global proxies in the delayed development scenario

Decomposing the vulnerability-resilience indicator into its proxies shows clearly the difference in income progression between the rapid growth and delayed development scenario. Ecosystem sensitivity is due to the projected increase in fertilizer use.

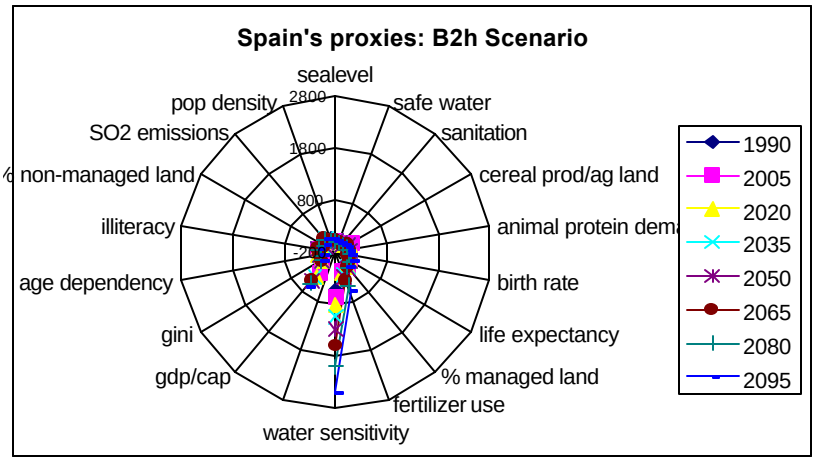

Figure A- 32 Spain's proxies in the local sustainability scenario

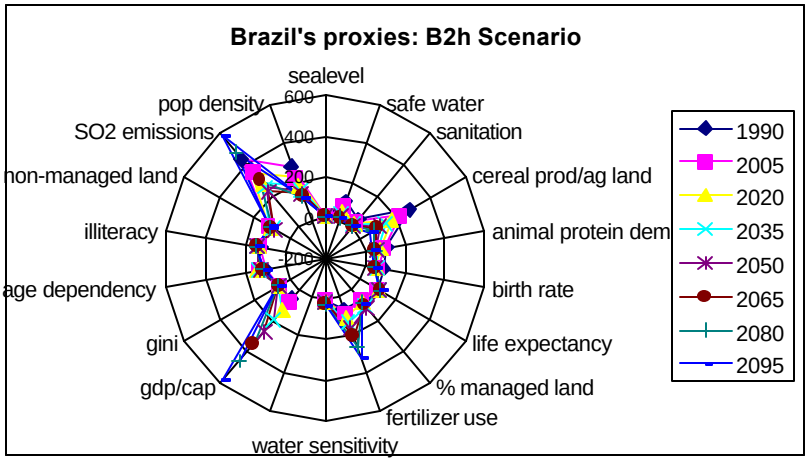

Figure A- 33 Brazil's proxies in the local sustainability scenario

Comparing Spain and Brazil's proxy values over time, we find that Spain becomes extremely sensitive to water availability. No major rivers supply Spain with water

Mexico and Brazil differ in the assumed impact of sulfur emissions. It becomes now even more evident that two countries from the same MiniCAM region show very different patterns for their proxies over time.

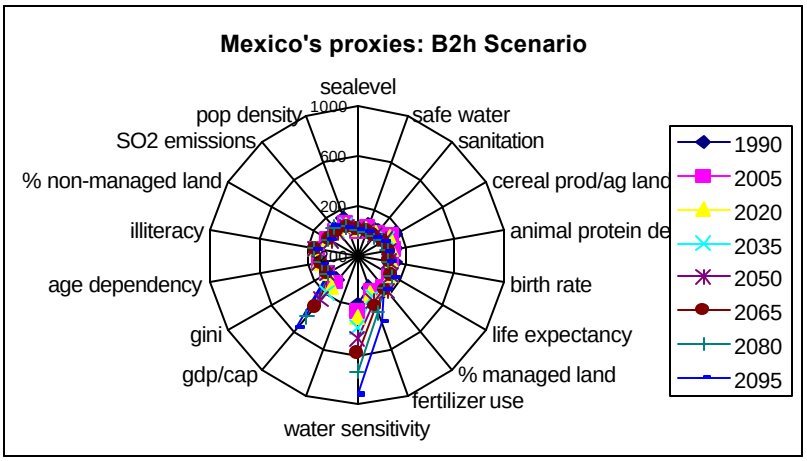

Figure A- 34 Mexico's proxies in the local sustainability scenario

Senegal's Figures A35, A36, and A37 depict the proxy patterns for the three scenarios. Different patterns show up. For the B2h (local sustainability) scenario the risk of the population to sea level rise is large. In the rapid growth scenario economic growth shows as the most dominant proxy; in the delayed development scenario the most relevant proxies are seemingly the risk of sea level rise and the sulfur emissions.

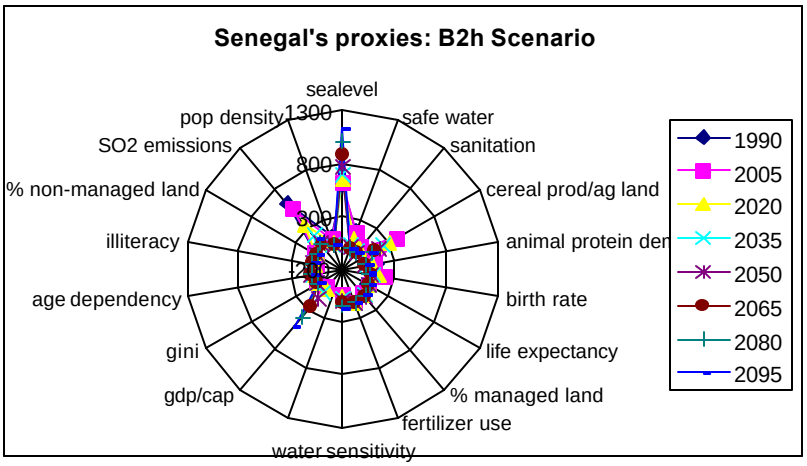

Figure A- 35 Senegal's proxies in the local sustainability scenario

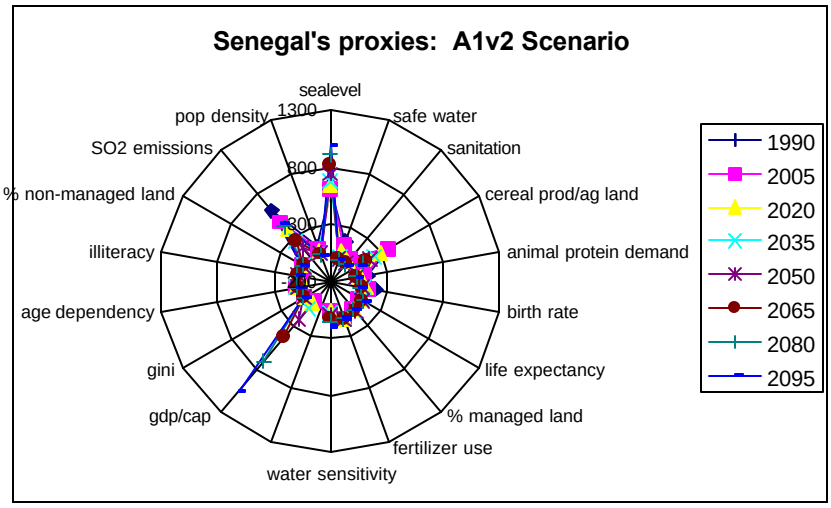

Figure A- 36 Senegal's proxies in the rapid growth scenario

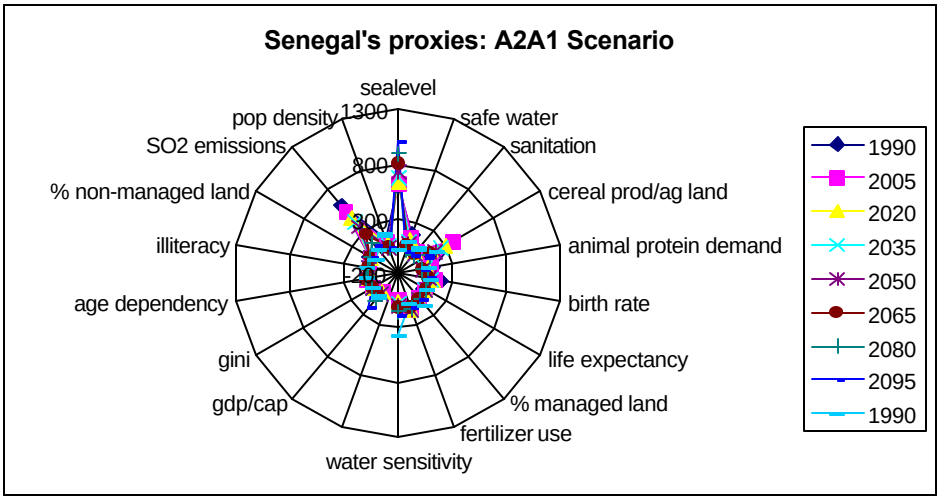

Figure A- 37 Senegal's proxies in the delayed development scenario

Results from sampling the proxies from narrow probability distributions and calculating the indicator values

We performed 1000 indicator calculations at each point in time, that is, at 15-year intervals, with the indexed proxies obtained through stratified Latin hypercube sampling from narrow normal probability distributions amounting to a 2% coefficient of variation around the best estimate of the proxies. We then calculated the squared Pearson correlation coefficients between each of the proxies and the vulnerability-resilience (VR) indicator as a measure of proxy contribution to the uncertainty in vulnerability for a point in time for a country under a specific climate change scenario. The correlation coefficients represent the amount of variance explained of the indicators by the proxies. The bar graphs in the figures below represent these stacked squared correlations as Percentage contributions to the variance of the indicators.

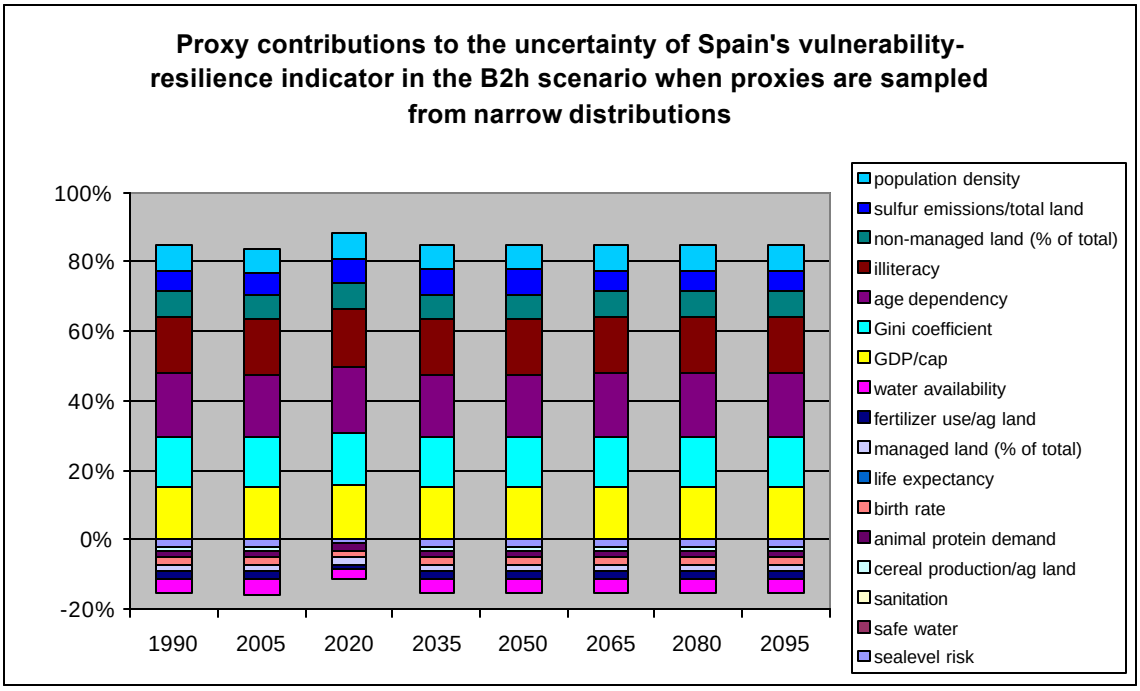

Figure A- 38 Percentage contributions by proxies, when varied 2%, to the uncertainty of Spain's vulnerability-resilience indicators from 1990 through 2095 for the local sustainability scenario

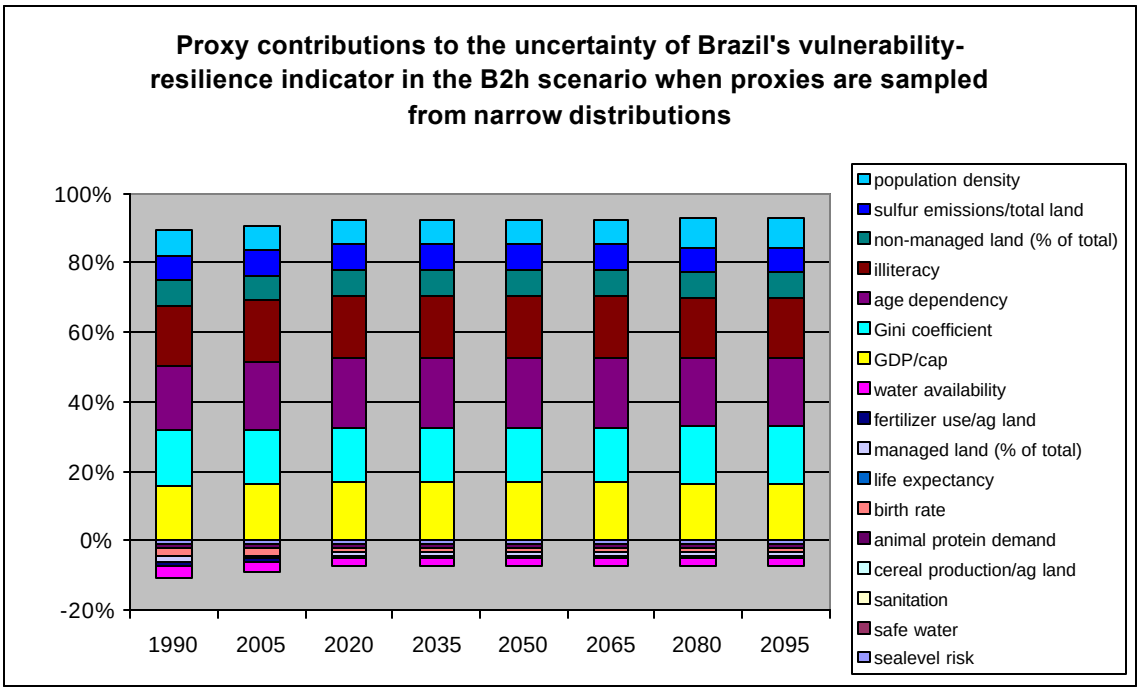

Figure A- 39 Percentage contributions by proxies, when varied 2%, to the uncertainty of Brazil's vulnerability-resilience indicators from 1990 through 2095 for the local sustainability scenario

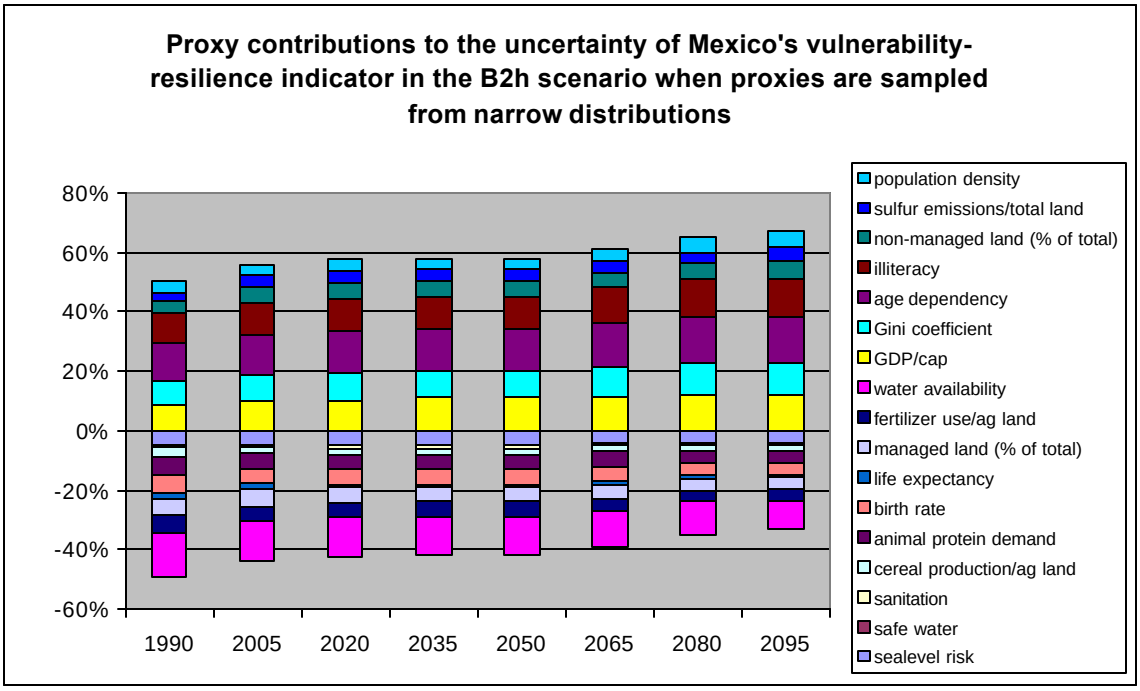

Figure A- 40 Percentage contributions by proxies, when varied 2%, to the uncertainty of Mexico's vulnerability-resilience indicators from 1990 through 2095 for the local sustainability scenario

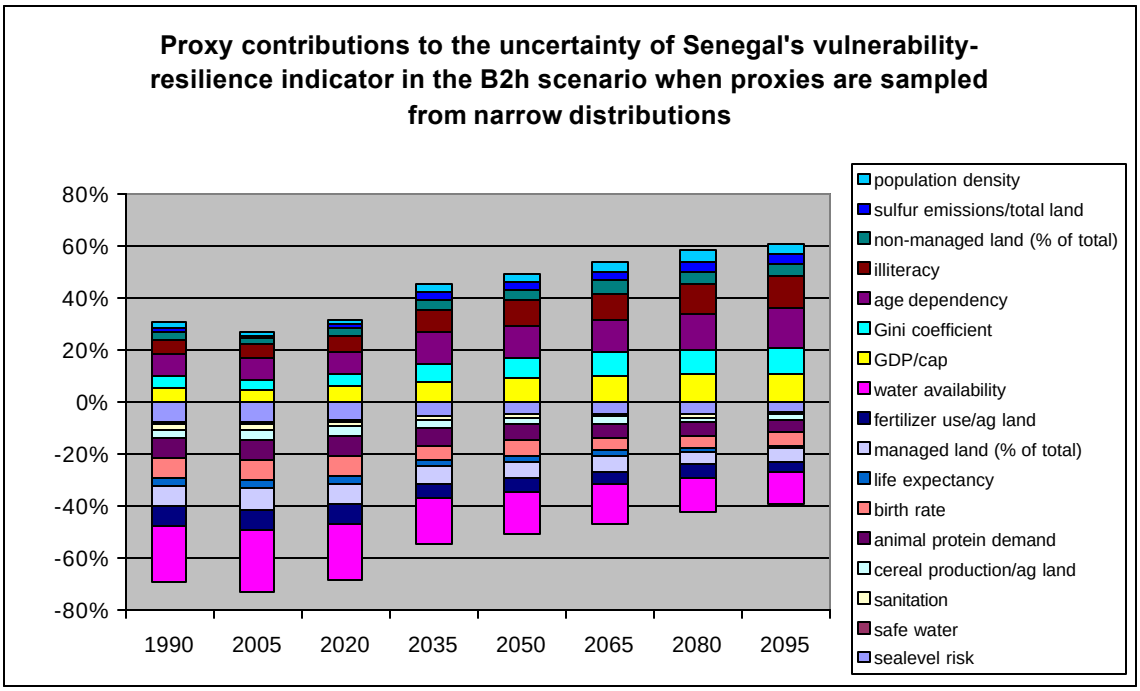

Figure A- 41 Percentage contributions by proxies, when varied 2%, to the uncertainty of Senegal's vulnerability-resilience indicators from 1990 through 2095 for the local sustainability scenario

The country graphs above for Spain, Brazil, Mexico and Senegal show very similar proxy patterns, differing only to the degree they affect either the sensitivity or the coping-adaptive capacities of the countries. Thus, the more vulnerable a country is, the greater the emphasis on the proxies representing the sensitivity to climate impact, while the more resilient a country is, the emphasis is on the proxies representing coping and adaptive capacity. Spain and Brazil have high coping-adaptive capacities , while Mexico, for which the proxies are projected over time through the same regional forecasts as for Brazil, remains much more climate-sensitive. Senegal also shows high vulnerability and a relatively large change over time compared to the other countries. The similarity of the patterns illustrates that sampling from narrow distributions reveals the consequences of the model structure, in our case, calculation hierarchy. Access to clean water and sanitation barely show as contributing, given that they are each one of three proxies in the settlement sensitivity indicator that are averaged before that average is averaged with the third proxy, the population at risk due to sea level rise. In contrast, water availability is always apparent given that that is the only proxy standing for the water sensitivity indicator (see also the discussion in the main body of the report).

Results from sampling the proxies from ranges based on the changes in the proxies' values over time

The results of performing a 1000 indicator calculations at each point in time, that is, at - year intervals, with the indexed proxies obtained through stratified Latin hypercube sampling from distributions representing the 30-year change over time around the proxies' best-estimate values at each point in time, are shown for the countries previously graphed in Figures A1-A12. The upper and lower limits of the sampling range of the proxies are the values these proxies have either 15 years before or 15 years after the time of calculations. We again calculated the squared

Pearson correlation coefficients between each of the proxies and the vulnerability-resilience indicator as a measure of proxy contribution to the uncertainty in vulnerability for that point in time for a country under each of the scenarios. The bar graphs in the figures below (Figures A42 and A45-A55) represent these stacked squared correlations as percentage contributions to the variance of the indicators.

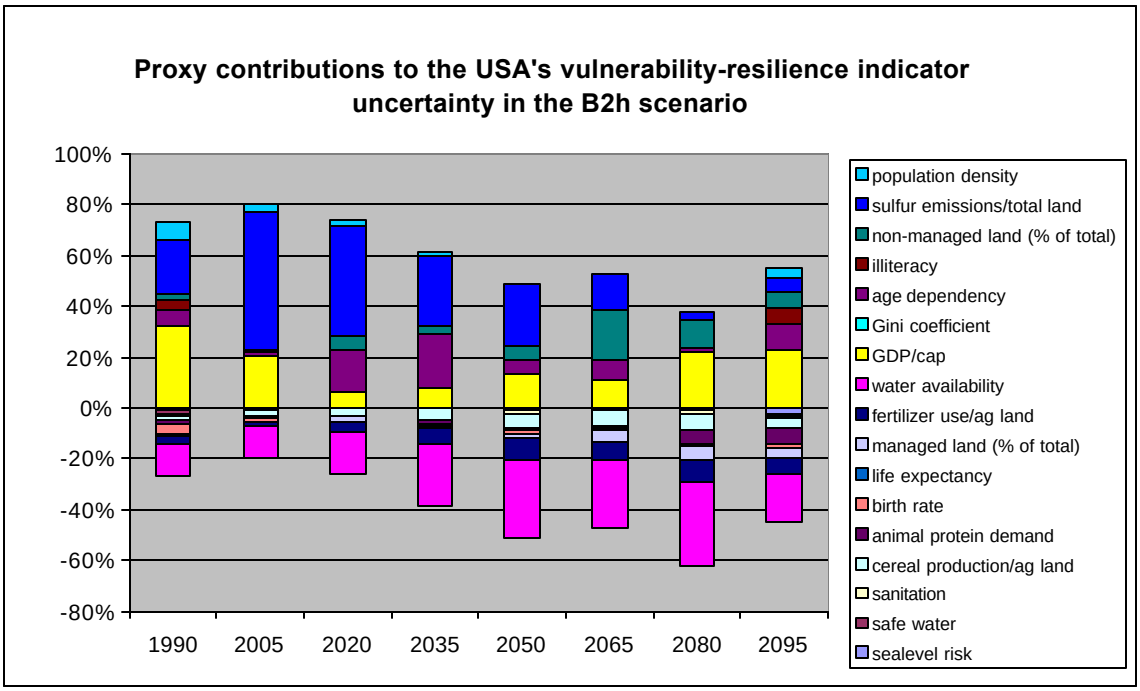

Figure A- 42 Percentage contributions by proxies to the uncertainty of the USA's vulnerability-resilience indicators from 1961 through 2095 for the local sustainability scenario with proxies sampled from ranges determined by changes in proxy values over time

By performing this type of uncertainty analysis with proxy variances based on projected trends, we find that model structure effect is still apparent, that proxy values have impact and that significant changes in proxy values, resulting in a large ranges from which proxies are sampled, translate in significant contributions to the uncertainty of the final indicator.

Figures A43 and A44 show the proxy values and proxy variances used in obtaining the results of Figure A42. Bar 2 (year 2005, Figure A42) in Figure 42 illustrates the effect of the large variance in sulfur emissions in 2005 (Figure A44). Bar 6 (year 2065, Figure A42) illustrates the effect the relative large variance % non-managed land has (Figure A44). The beneficial effect of reduced sulfur emissions reduces overall vulnerability in 2005. That water availability is always visible as a relevant proxy is model-structure dependent but also dependent n the relative large changes that occur for that proxy. Cereal production only shows itself after the variance in for example sulfur emissions are of a similar magnitude. And as can be observed in Figure 43, the value of the cereal proxy is low compared with many of the other indexed proxies.

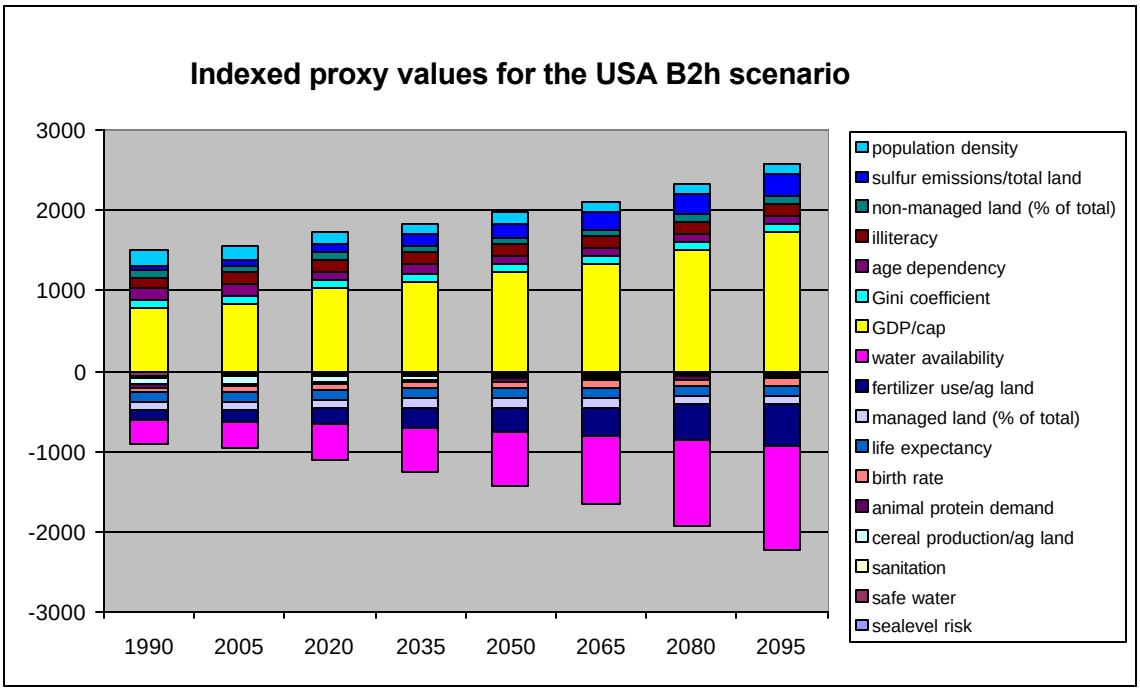

Figure A- 43 Values of the proxies after indexing against world baseline data for the USA's B2h scenario

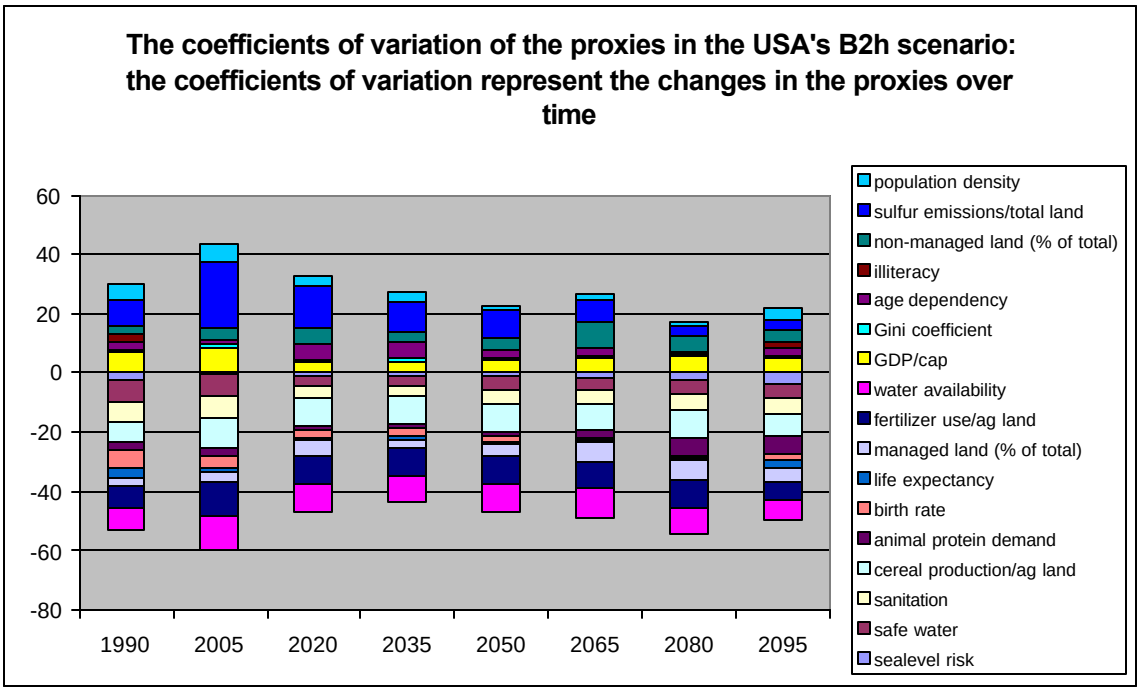

Figure A- 44 The coefficients of variation of the proxies after indexing in the USA's B2h scenario

Figures A45-A55 only show the proxy contribution results of the different countries. For Canada age dependency and GDP per capita are leading proxies. For Japan the pattern is very varied with sulfur emissions, water availability, GDP per capita and age dependency clearly leading. For

Australia, its high coping and adaptive capacity can be explained by the land use proxy, the GDP per capita and age dependency while in 2050 fertilizer use negatively affects Australia's sensitivity. For Poland we find by the year 2020 economic growth dominating while after 2065 reductions in sulfur emissions have a beneficial effect. China's leading proxies are economic growth for all points in time, and reduction in sulfur emissions after 2050 while water availability is also an important proxy. For Jordan p density is evident. For Egypt percentage managed land is a very important proxy till the year 2020 when a relative large variety of proxies share in the explanation of the variance of the VR indicator. For Mexic o it is largely GDP per capita, water availability and sulfur emissions. For Bangladesh a relatively large number of the sensitivity proxies are important, e.g., access to safe water and sanitation, cereal production, fertilizer use, birth rate and water availability. In 2065 land use becomes evident and after 2065 sulfur emissions. GDP per capita plays a role at each point in time. For India it is similar, except that land use does not show in 2065 and the balance between the sensitivity and coping-adaptive proxies differs somewhat. For Thailand the coping and adaptive capacity is larger, manifesting itself in the GDP per capita proxy and the sulfur emissions.

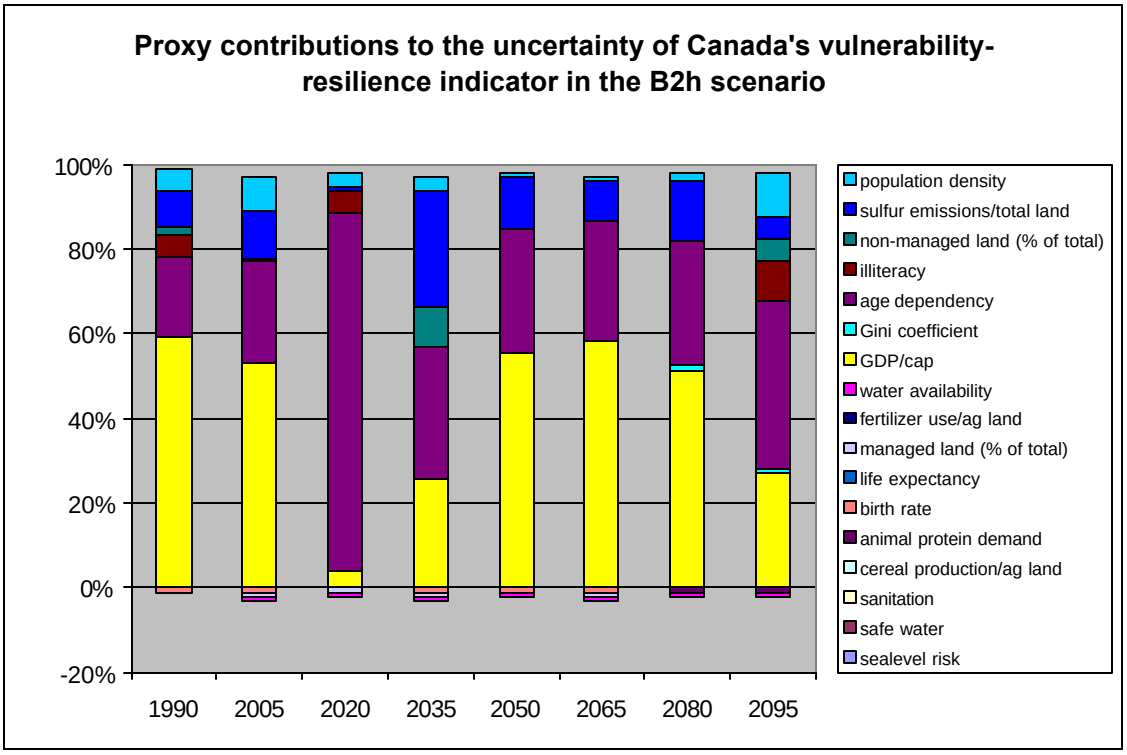

Figure A- 45 Percentage contributions by proxies to the uncertainty of Canada's vulnerability-resilience indicators from 1961 through 2095 for the local sustainability scenario with proxies sampled from ranges determined by changes in proxy values over time

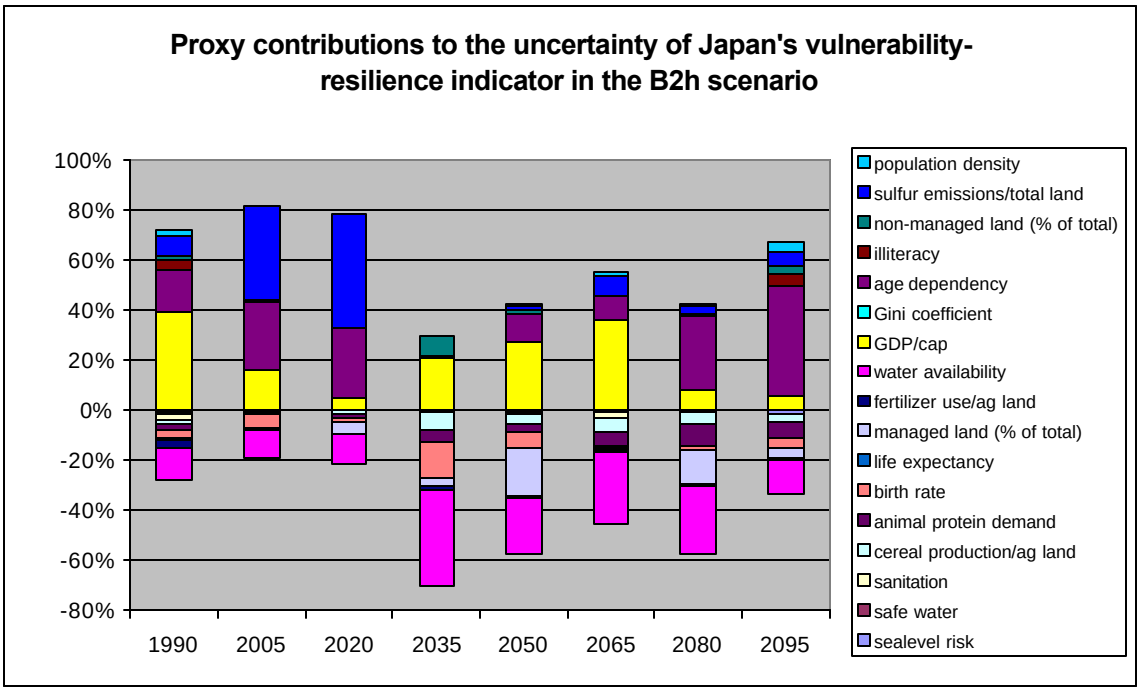

Figure A- 46 Percentage contributions by proxies to the uncertainty of the Japan's vulnerability-resilience indicators from 1961 through 2095 for the local sustainability scenario with proxies sampled from ranges determined by changes in proxy values over time

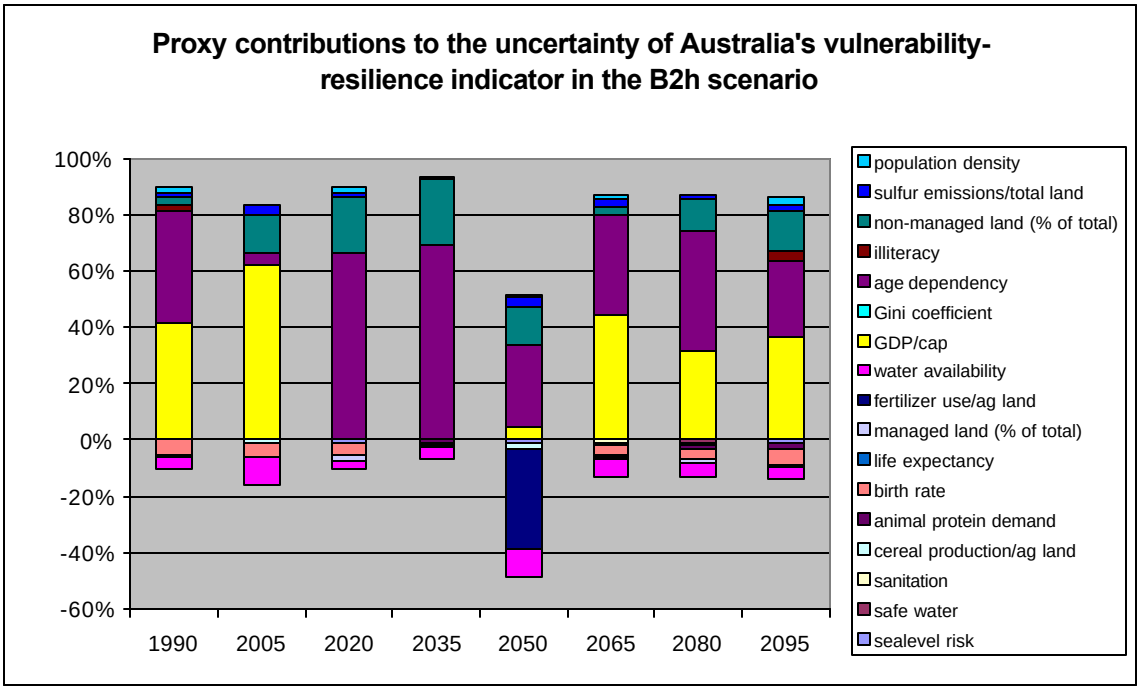

Figure A- 47 Percentage contributions by proxies to the uncertainty of the Australia's vulnerability-resilience indicators from 1961 through 2095 for the local sustainability scenario with proxies sampled from ranges determined by changes in proxy values over time

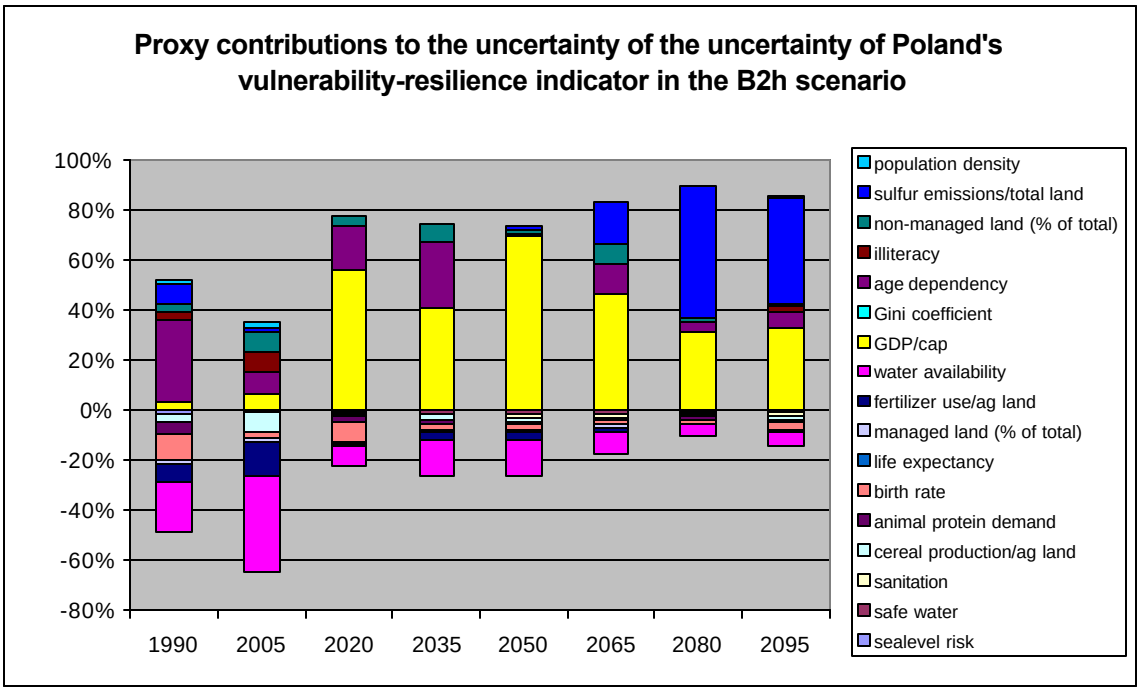

Figure A- 48 Percentage contributions by proxies to the uncertainty of the Poland's vulnerability-resilience indicators from 1961 through 2095 for the local sustainability scenario with proxies sampled from ranges determined by changes in proxy values over time

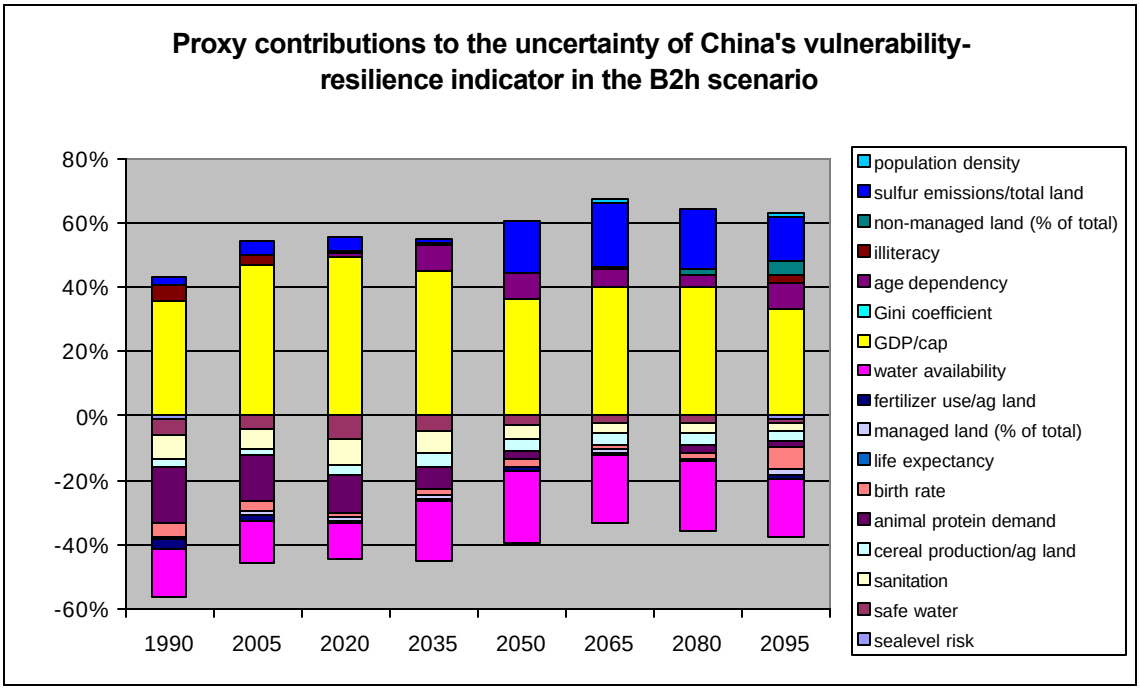

Figure A- 49 Percentage contributions by proxies to the uncertainty of the China's vulnerability-resilience indicators from 1961 through 2095 for the local sustainability scenario with proxies sampled from ranges determined by changes in proxy values over time

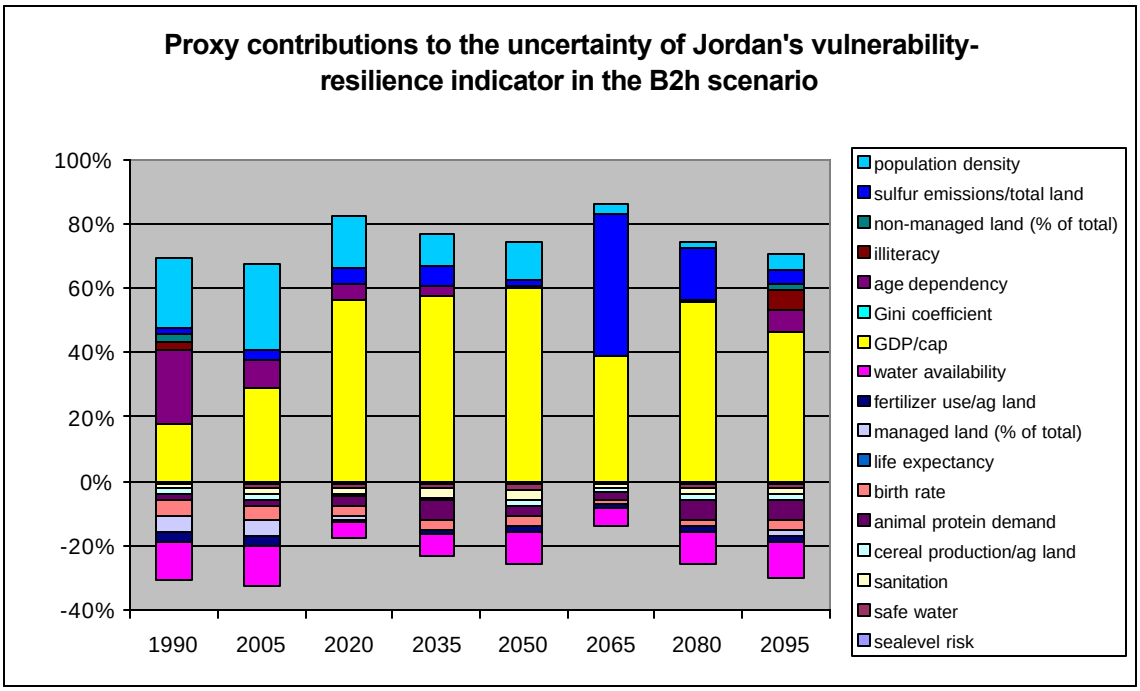

Figure A- 50 Percentage contributions by proxies to the uncertainty of the Jordan's vulnerability-resilience indicators from 1961 through 2095 for the local sustainability scenario with proxies sampled from ranges determined by changes in proxy values over time

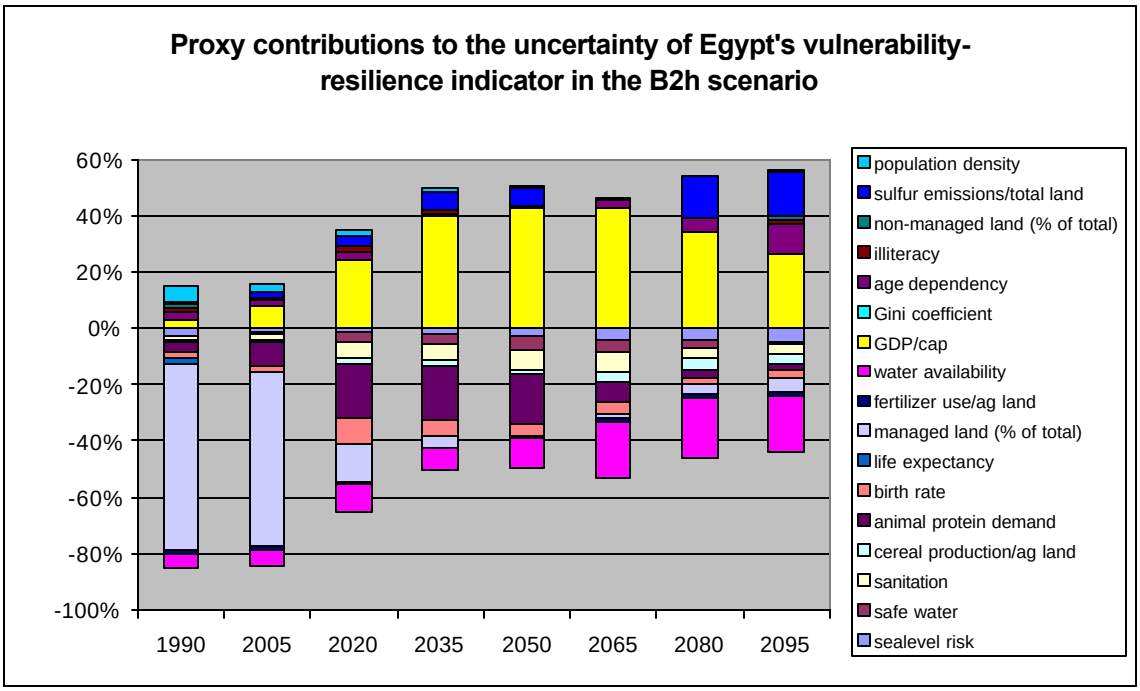

Figure A- 51 Percentage contributions by proxies to the uncertainty of the Egypt's vulnerability-resilience indicators from 1961 through 2095 for the local sustainability scenario with proxies sampled from ranges determined by changes in proxy values over time

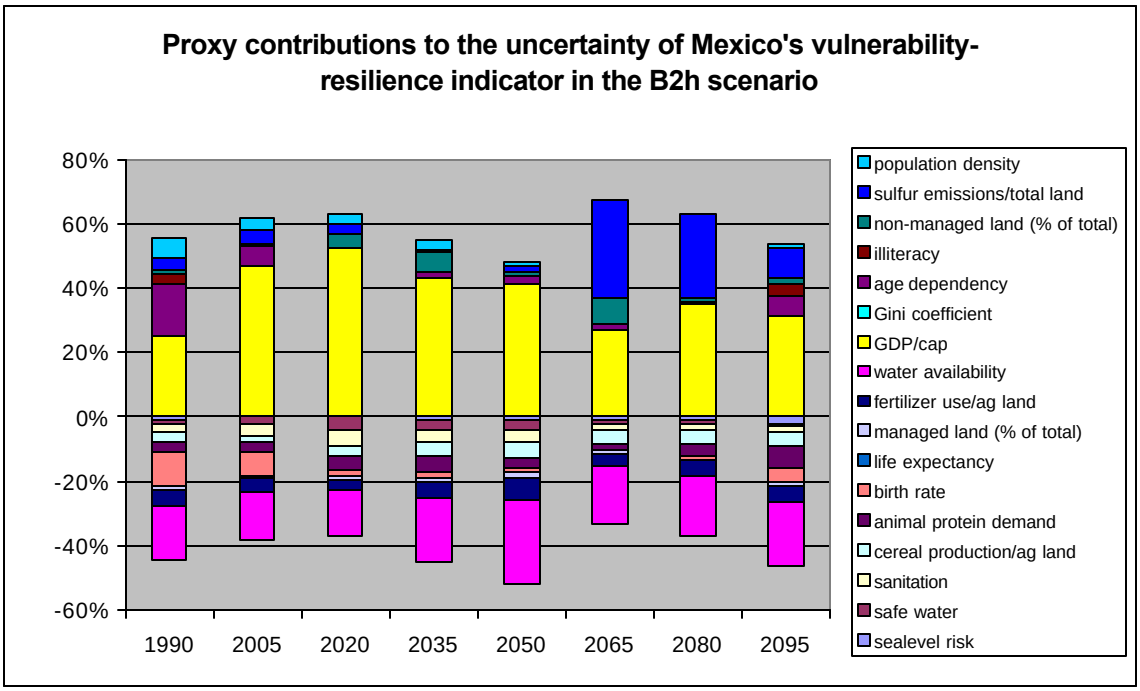

Figure A- 52 Percentage contributions by proxies to the uncertainty of the Mexico's vulnerability-resilience indicators from 1961 through 2095 for the local sustainability scenario with proxies sampled from ranges determined by changes in proxy values over time

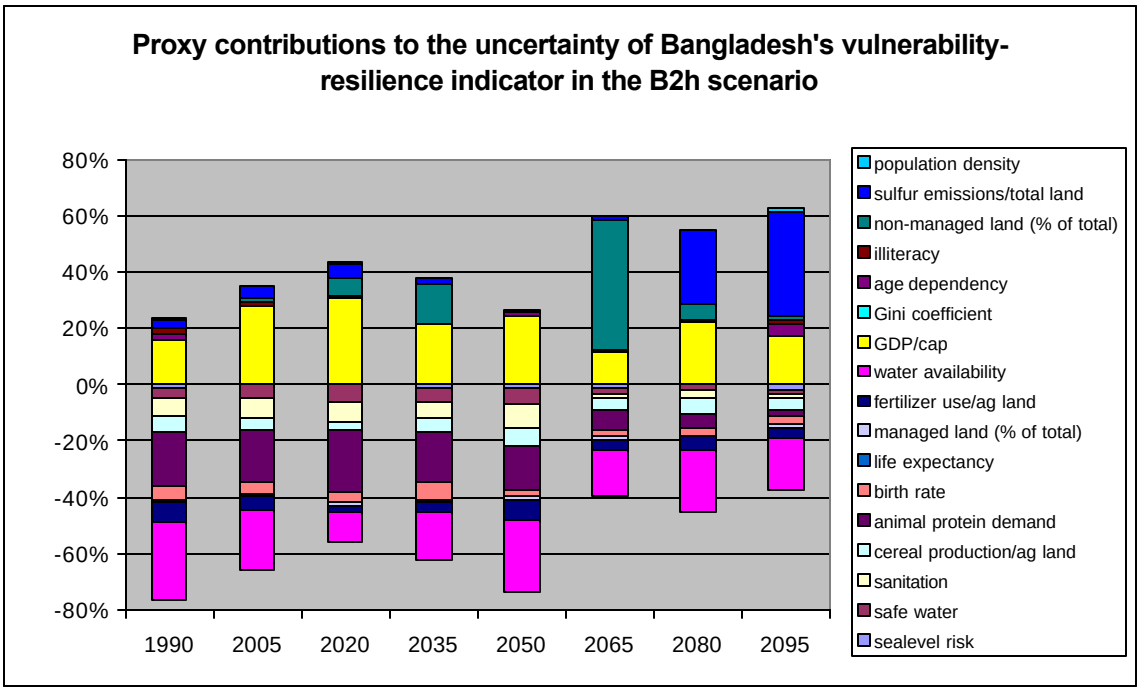

Figure A- 53 Percentage contributions by proxies to the uncertainty of the Bangladesh's vulnerability-resilience indicators from 1961 through 2095 for the local sustainability scenario with proxies sampled from ranges determined by changes in proxy values over time

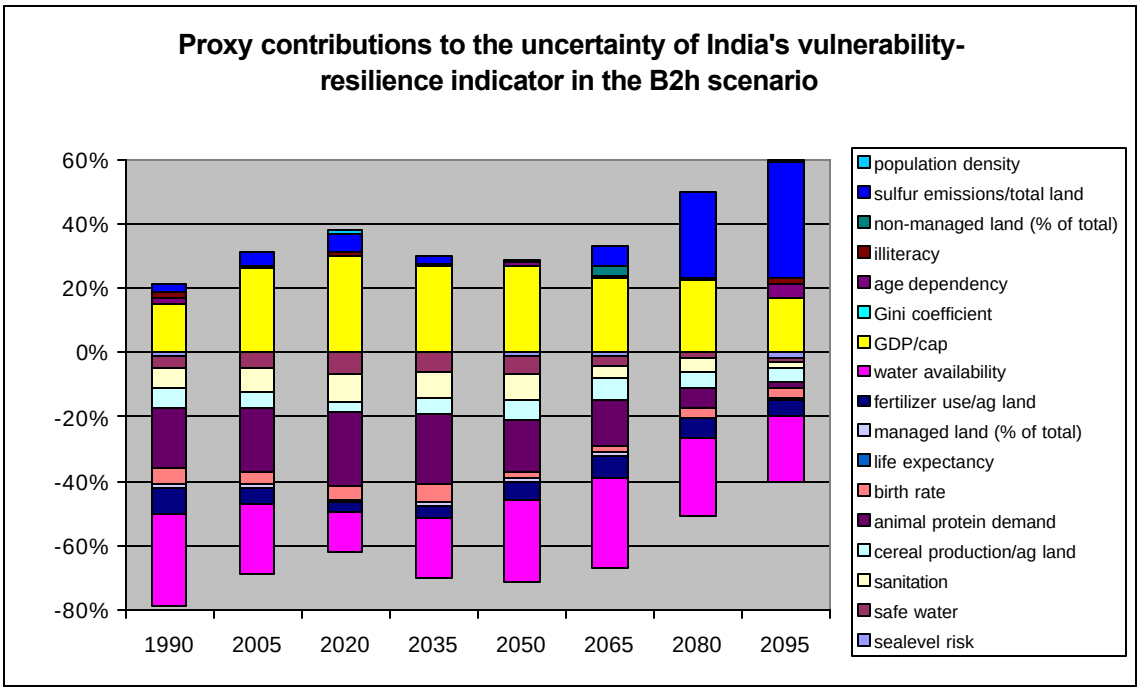

Figure A- 54 Percentage contributions by proxies to the uncertainty of the India's vulnerability-resilience indicators from 1961 through 2095 for the local sustainability scenario with proxies sampled from ranges determined by changes in proxy values over time

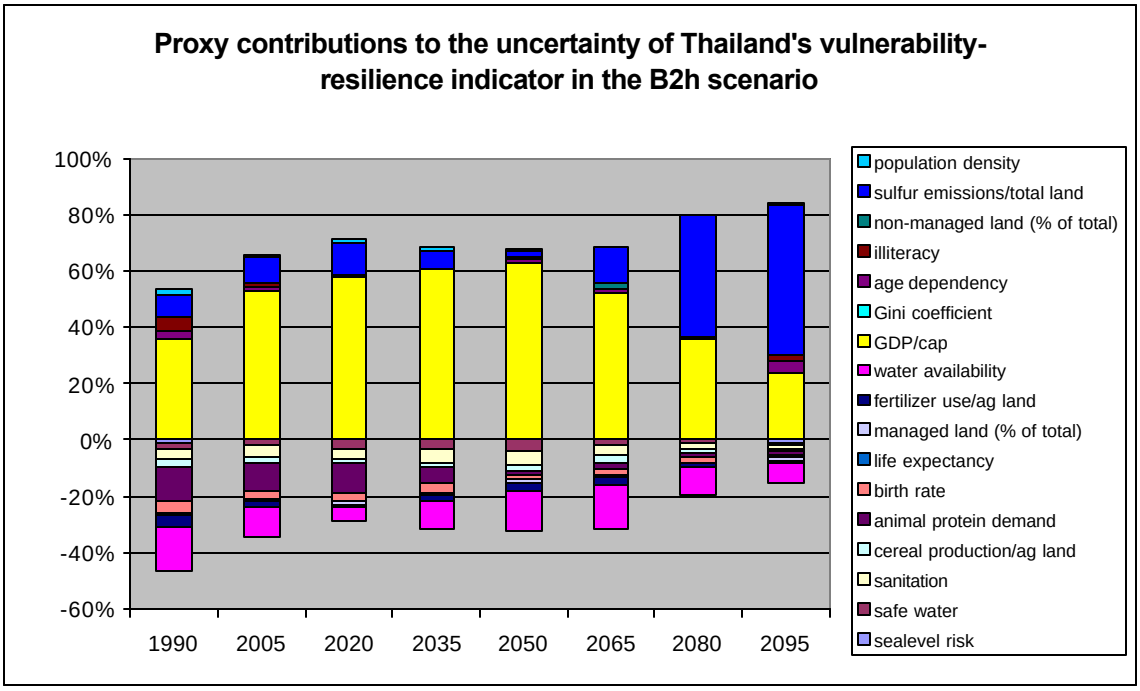

Figure A- 55 Percentage contributions by proxies to the uncertainty of the Thailand's vulnerability-resilience indicators from 1961 through 2095 for the local sustainability scenario with proxies sampled from ranges determined by changes in proxy values over time

Thus, by performing this type of uncertainty analysis with proxy variances based on historical or projected trends, we see all aspects from our previous analyses emerge: model structure effect remains apparent, the proxy values themselves play their role in determining proxy contributions to the uncertainty of the final indicator and in addition it is now shown that when the proxies change significantly over any 30 year time period, the proxies show up as potentially explaining more of the variance and value of the final indicator, but that that contribution is still model structure dependent.

If we define dominant or leading proxies as proxies that, when having different values, have significant impacts on final indicator values than those proxies with the highest explanatory power of the variance of the calculated indicators may be called leading proxies.