The variables associated with disaster risk through statistical analysis were physical exposure and the percentage of population with access to improved water supply. A strong correlation was established (R^2 = 0.81) indicating the solidity of the method as well as the reliability of these datasets for such a scale of analysis.

Figure T.9 shows the distribution (on a logarithmic scale) of expected deaths from drought and as predicted from the model. A clear regression can be drawn. It should be noted that if Ethiopia were to be excluded, the correlation would fall to (R^2 = 0.6). However, the offset and the slope of the regression line do not change significantly, reinforcing the robustness of the model.

As far as 1.26 is close to 1, the number of killed people grows proportionally to physical exposure. Also, the number of killed people decreases as a percentage of population when improved water supply grows. This latter variable should be seen as an indicator of the level of development of the country, as it was correlated to other development variables, such as the under-five mortality rate (Pearson correlation r = –0.64) and Human Development Index (r = 0.65).

Some countries with large physical exposure did not report any deaths to drought (United States of America, Viet Nam, Nigeria, Mexico, Bangladesh, Iran, Iraq, Colombia, Thailand, Sri Lanka, Jordan, Ecuador). This could be for a number of reasons. Either the vulnerability is null or extremely low, e.g. USA and Australia, or the number of reported killed from food insecurity is placed under conflict in EM-DAT, e.g. Iraq and Angola. For other countries, further inquiry might be necessary.

T.6 Multiple Risk Integration

So far, the precision and quality of the data as well as the sensitivity of the model do not allow the ranking of countries for disaster risk.

T.6.1 Methods

How to compare countries and disasters

A multiple-hazard risk model was made by adding expected deaths from each hazard type for every country. In order to reduce the number of countries with no data that would have to be excluded from the model, a value of 'no data' for countries without significant exposure was replaced by zero risk of deaths. Countries were considered as not affected if the two following conditions were met: a physical exposure smaller than 2 percent of the national population AND an affected population smaller than 1,000 per year.

Some 39 countries were excluded from the analysis. Despite this, it is known that each was exposed to some level of hazard and 37 countries with recorded disaster deaths were in EM-DAT. This list of countries identifies places where improvement in data collection is needed to allow their integration in future work. Reasons that individual countries were excluded were: countries marginally affected by a specific hazard, countries affected but without data; and countries where the distribution of risk could not be explained by the model (for example, for drought in Sudan, where food insecurity and famine is more an outcome of armed conflict than of meteorological drought as defined in the model).

Once the countries to be included in the model were identified, a Boolean process was run to allocate one of five statistically defined categories of multi-hazard risk to each country. Figure T.10 illustrates the different steps taken to incorporate values into a multiple-risk index. Once this process had been completed, three different products were available:

- A table of values for the countries that include the data for relevant hazards or countries without data but marginally affected (210 countries).
- A list of countries with missing data (countries with reported deaths but without appropriate data).
- A list of countries where the model could not be applied (indicators do not capture the situation in these countries, case of countries not explained by the model, or rejected during the analysis because the indicators are not relevant to the situation).

Multiple risk computation

Multiple risk was computed using the succession of formulae as described in Equation 15 (see following page).

Between each addition, the whole process described in Figure T.10 (see following page) needed to be run in order to identify those countries where a value represented by zero needed, either to be replaced by a value calculated from the selected hazard model, or if not, the country was placed in the 'not-relevant' or 'no data' lists (see below).

EQUATION 15 COMPUTATION OF MULTIPLE RISK BY SUMMING CALCULATED DEATHS AS MODELLED FOR RISK FOR CYCLONE, FLOOD, EARTHQUAKE AND DROUGHT

EQ15

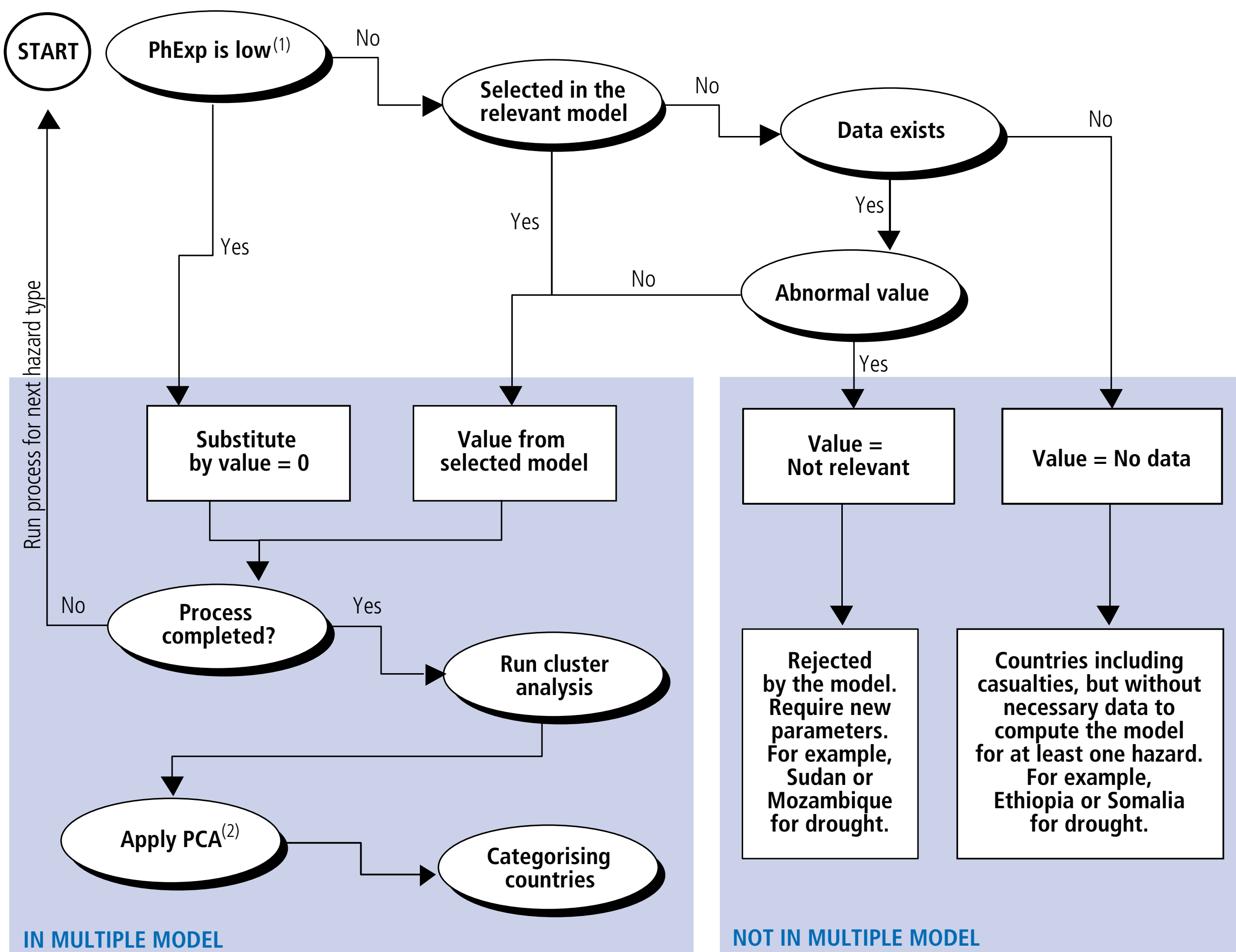
$$K_{cyclones}\,(PhExp_{cyclones}^{0.63} \bullet \overline{Pal}^{0.66} \bullet \overline{HDI}^{-2.03} \bullet e^{-15.86}) + K_{floods}\,(PhExp_{floods}^{0.78} \bullet GDP_{cap}^{-0.45} \bullet D^{-0.15} \bullet e^{-5.22}) +$$

$$K_{earthquakes}\,(PhExp_{earthquakes}^{1.26} \bullet U_g^{12.27} \bullet e^{-16.27}) + K_{droughts}\,(PhExp3\_50^{1.26} \bullet WAT_{TOT}^{-7.58} \bullet e^{14.4})$$

Where

e	is the Euler constant (=2.718…)
PhExp	is the physical exposure of selected hazard
HDI	is the Human Development Index
GDP_{cap}	is the Gross Domestic Product per capita at purchasing power parity
D	is the local density (density of population in the flooded area)
U_g	is the Urban growth (computed over three-year period)
WAT_{TOT}	is the access to safe drinking water

FIGURE T.10 MULTIPLE RISK INTEGRATION



(1) Physical exposure is considered as marginal if smaller than 1,000 per year
(2) PCA: Principal Component Analysis, used to combine killed per year and killed per population in one component.

In order to examine the fit between model multi-hazard risk and recorded deaths, data from both sources were categorised into five country risk classes. A cluster analysis minimising the intra-class distance and maximising the inter-classes (K-means clustering method) was performed. This meant that a purely statistical process had been used to identify severities of risk from the model and deaths as recorded by EM-DAT.

In order to take both risk indicators (killed and killed per inhabitant) into account, a Principal Component Analysis (PCA) was performed to combine the two. Then a distinction was made between countries smaller than 30,000 km squared and with population density higher than 100 inhabitants per km squared.

T.6.2 Results

Modelled countries without reported deaths

The multi-hazard DRI was computed for 210 countries. This includes 14 countries where no recorded deaths were reported in the last two decades from EM-DAT: Barbados, Croatia, Eritrea, Gabon, Guyana, Iceland, Luxembourg, Namibia, Slovenia, Sweden, Syrian Arab Republic, The former Yugoslav Republic of Macedonia, Turkmenistan and Zambia.

No data, abnormal values and specific cases

Through the Principal Component Analysis transformation, inferior and superior thresholds were identified. This was performed on both observed and modelled deaths. For 14 countries, a value was calculated in the multi-hazard risk model even though no deaths had been recorded by EM-DAT in the 1980-2000 period. On the other hand, 37 countries where deaths were recorded could not be modelled, either because of a lack of data or because they did not fit with the model assumptions. These countries were: Afghanistan, Azerbaijan, Cuba, Democratic People's Republic of Korea, Democratic Republic of the Congo, Djibouti, Dominica, France, Greece, Liberia, Malaysia, Montserrat, Myanmar, New Caledonia, Portugal, Solomon Islands, Somalia, Spain, Sudan, Swaziland, Taiwan, Tajikistan, Vanuatu, Yugoslavia, Antigua and Barbuda, Armenia, Guadeloupe, Guam, Israel, Martinique, Micronesia (Federated States of), Netherlands Antilles, Puerto Rico, Reunion, Saint Kitts and Nevis, Saint Lucia, United States Virgin Islands.

Countries absent of both EM-DAT and Model

Two countries were absent from both EM-DAT and the model: Anguilla (a dependency of the United Kingdom) and Bosnia-Herzegovina.

EM-DAT-DRI multi-hazard risk comparison results

The results of the comparison of modelled and EM-DAT multi-hazard deaths are presented and discussed in Chapter 2. For more information, including country specific variables, researchers are encouraged to visit the Report website.

T.7 Technical Conclusions and Recommendations

T.7.1 The DRI – A work in progress

The DRI is a statistically robust tool

The results generated by the DRI method were statistically robust with a high level of confidence. This is especially the case considering the independence of the data sources and the coarse resolution of the data available at the global scale. The statistically strong links — both between observed and modeled deaths and between socio-economic variables associated with human vulnerability and levels of risk — that were found in the DRI study are not often found in similar studies that analyse geophysical datasets and socio-economic data. The model has succeeded in opening the great potential for future national level disaster risk assessments. It provides the first, solid statistical base for understanding and comparing countries' disaster risk and human vulnerability.

The DRI is not a predictive model

This is partly a function of a lack of precision in the available data. But it also shows the influence of local context. The risk maps provided in this research allow a comparison of relative risk between countries, but cannot be used to depict actual risk for any one country. Sub-national risk analysis would be required to inform development and land-use planning at the national level.

How to link extreme and everyday risk?

Extraordinary events by their very nature do not follow the normal trend. Hurricane Mitch in 1998, the rains causing landslides in Venezuela in 1999 or the 1988 earthquake in Armenia were off the regression line. This is due to the abnormal intensity of such events. These events are (hopefully) too rare to be usefully included in a two-decade period of study. Incorporating this level of intensity can only be done on an event-per-event approach.

T.7.2 Ways forward

Socio-economic variables

Results showed that global datasets can still be improved both in terms of precision and completeness. However, they already allow the comparison of countries. Other indicators — such as a corruption, armed conflict or