Global Risk And Vulnerability Index Trends per Year (GRAVITY)

Phase III: Drought analysis

<u>Technical report for</u>:

United Nations Development Programme
Bureau of Crisis Prevention & Recovery (UNDP/BCPR)

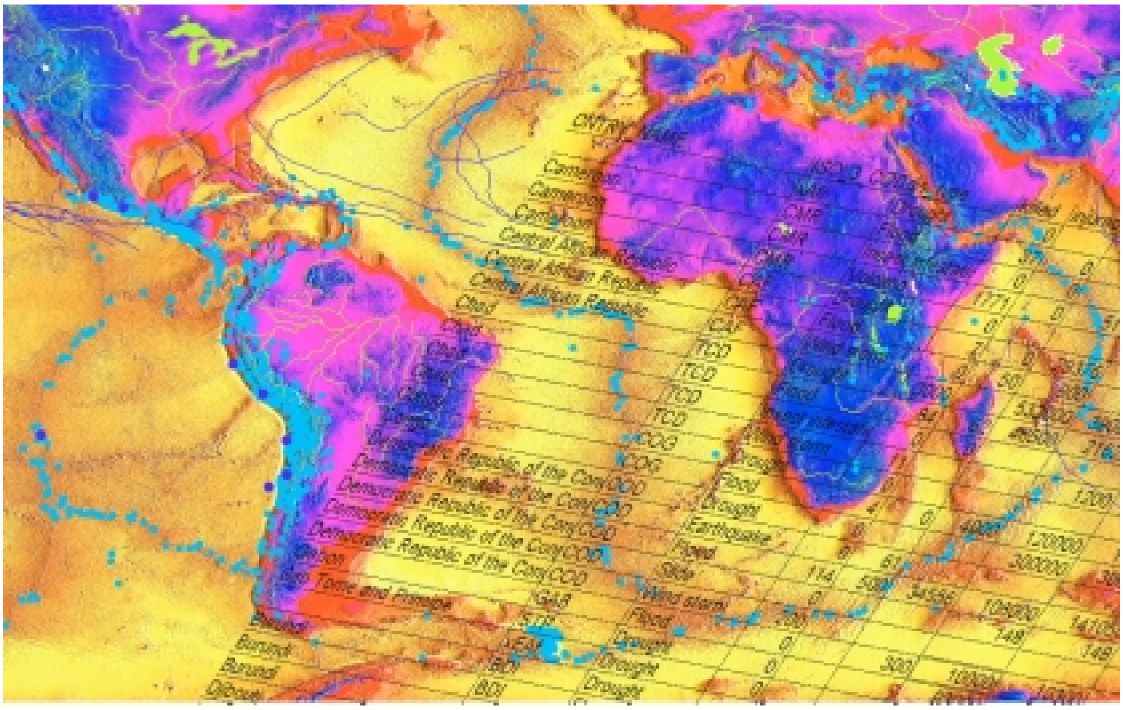

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Table of acronyms

AGR_{EMP}	Percentage of labour force in agricultural sector
BCPR	Bureau for Crisis Prevention and Recovery
CRED	Centre for Research on Epidemiology of Disasters
FAO	Food and Agriculture Organisation
GDP_{AGR}	Percentage of agriculture's dependency for GDP
GDP_{CAP}	Gross Domestic Product per capita
GEO	Global Environment Outlook
GIS	Geographical Information System
GLASOD	Human Induced Soil Degradation
GRAVITY	Global Risk And Vulnerability Index Trend per Year
HDI	Human Development Index
HPI	Human Poverty Index
IFRC	International Federation of the Red Cross
IRI	International Research Institute for Climate Prediction
ISDR	International Strategy of Disaster Reduction
PhExp	Physical Exposure (if not specified, for drought)
$U5_{MORT}$	Under five years old mortality rate
UNDP/BCPR	United Nation Development Programme, Bureau for Crisis Prevention and Recovery
UNEP/GRID	United Nation Environment Programme, Global Resource Information Database
WAT_{RUR}	Percentage of population having access to improved water supply in rural area
WAT_{TOT}	Percentage of population having access to improved water supply
WAT_{URB}	Percentage of population having access to improved water supply in urban area

INTRODUCTION

Among the different recommendations from the two previous GRAVITY reports, drought was the obvious significant missing hazard. In the first GRAVITY report (feasibility study) food insecurity was highlighted for producing the largest amount of casualties. Nevertheless, due to time restriction and complexity to model such hazard, this important issue was left unstudied. The problem for the UNDP World Vulnerability Report (WVR) was that if drought was not included, a global approach on vulnerability to human development would not be achieved: as most of Africa is deeply affected by such events.

Drought and food insecurity: a complex hazard

Drought isn't purely a natural hazard as it includes strong human induced causes (such as conflicts, bad governance,...). Even when dealing with the physical drought component, the lack of precipitation has fuzzy boundaries and it is therefore very difficult to draw a line between regions affected by drought and others. The duration of a drought also causes significant problems, not only the beginning and end of an event is difficult to specify, but some drought last for several years and continue to affect populations long after precipitation have return to normal. This is due to long term effects on human organisms, as well as decline of agriculture capabilities through soil deterioration and lack of seeds for new plantations.

Moreover, the same deficit in precipitation may not induce similar impacts depending on types of soil, vegetation and agriculture as well as differences in irrigation infrastructures. To further complicate this issue, the casualties are not resulting from physical drought but from food insecurity, thus including a human causes such as conflicts, political tensions, bad governance are even harder to model not even talking about international acceptance of such highly touchy subject.

Need for a simplification of the problem

In order to represent such complexity, a tremendous amount of data and knowledge is requested, which contributed to prevent the creation of a global data set during past decades. To overcome this problem, the study used a simple index designed by IRI at Colombia University (New York) based on deficit of precipitation. Then the GRAVITY team from UNEP/GRID-Geneva computed physical exposure and related vulnerability parameters. Although other components of food insecurity were misted out, the results were more successful than originally thought. It is believed that with the notable exceptions of Mozambique and Sudan where conflicts have too much implication on food insecurity, for the remaining countries, the physical drought has a sufficient influence on the ignition of such crisis to allow a correlation.

This study has not the pretension of having completed the subject, however it has initiated the movement and it is hoped that this will stimulate researches on this issue, thus leading to new improvements in the field of vulnerability toward natural hazards. Although the subject is not completed as other hazards needs to be added such as landslides, tsunamis or epidemics, it is believed that the gap has been sufficiently narrowed. New elements provided such data and methods gathered are now available to contribute to the first edition of the WVR.

1 DATA

1.1 Vulnerability indicators

The list of vulnerability indicators for drought and socio-economic data were provided by UNDP/BCPR.

In addition to socio-economical indicators used in GRAVITY-II a certain new number of requests were formulated in order to estimate the vulnerability to drought. However, the availability and quality of data has limited the number of new data sets to the following.

Table 1. Vulnerability indicators

Categories of vulnerability	Indicators	Sources
Economic	1. Gross Domestic Product per inhabitant at purchasing power parity, 2. Human Pauverty Index (HPI)	GEO
Type of economical activities	3. %age of agriculture's dependency for GDP 4. %age of labor force in agricultural sector	GEO
Dependency and quality of the environment.	5. Human Induced Soil Degradation (GLASOD)	UNEP
Development	6. Hu.man Development Index (HDI)	UNDP
Health and sanitation	7. %age of people with access to safe water (total, urban, rural) 8. Under five years old mortality rate	GEO GEO

GEO : Global Environment Outlook Data Portal (UNEP), based on data from FAO, WRI, World Bank and other sources / WB : World Development Indicators (World Bank) / TI : Transparency International / UNDP : Human Development Report (UNDP)

1.2 Population data

Extraction of population was based on the CIESIN, IFPRI, WRI Gridded Population of the World (GPW, Version 2) at a resolution of 2.5' (5 km at the equator). This choice was performed for reason stated in GRAVITY-II report. This layer was further completed by *Human Population and Administrative Boundaries Database for Asia* (UNEP) for Taiwan and CIESIN *Global Population of the world version 2* (country level data, 1995) for ex-Yugoslavia.

1.3 Data on victims

Data on victims was extracted from both EM-DAT and famine, The OFDA/CRED International Disaster Database, as of October 2002. The fusion between EM-DAT and famine database was performed by UNDP/BCPR and provided to UNEP/GRID-Geneva.

1.4 Precision and limitations

The same restriction of precision and limitations discussed in GRAVITY-II applies in this research, (please refer to Ch.2.4 of GRAVITY-II report), in addition to this a discussion on the precision of the data on drought is necessary.

1.5 Data sources

Countries borders dataset used: UNEP/GEO3 provided by UNWHO official dataset accepted as standard by the UN cartographic unit. Country names convention using the UNEP/GEO3 standards.

Table 2 Data sources for hazards

Theme	Data source	URL	Resolution/scale	Spatial units	Intensity	Frequency
Drought Physical drought	CMAP monthly gridded precipitation, Methodology and processing IRI/Columbia university. US National Centers for Environmental Prediction (NCEP), Climate Prediction Center (CPC)	http://iridl.ldeo.columbia.edu/	2.5 x 2.5 degree latitude/longitude grid	Grid cells	3 months 50% 3 months 75% 3 months 90% 6 months 50% 6 months 75% 6 months 90%	Number of events in 21 years January 1980 to December 2000

Table 3 Data sources for soil degradation

Theme	Data source	URL	Resolution/scale	Spatial units	Date	Unit
Soil degradation	ISRIC and UNEP/GRID-Geneva	http://www.grid.unep.ch/data/grid/index.html	1:10 000 000	Vector	1990	Soil degradation severity

Table 4 Data sources for victims

Theme	Data source	URL	Resolution/scale	Spatial units	Intensity	Frequency
Victims from drought	Université Catholique de Louvain : EM-DAT: The OFDA/CRED International Disaster Database merged with famine as performed by UNDP/BCPR.	http://www.cred.be/ emdat and famine as refined by UNDP/BCPR	n.a.	Countries	- - -	Frequency 1980 – 2000 (from EM-DAT)

Table 5. Data sources for population and vulnerability factors

Theme	Data source	URL	Resolution/scale	Spatial units	Values	Time range
Population (exposure)	CIESIN, IFPRI, WRI : Gridded Population of the World (GPW), Version 2	http://sedac.ciesin.org/plue/gpw/	2.5’ or 0.04167 degree ≅ 3.5 km in average	Grid cells	Population counts	1990, 1995
Population	Human Population and Administrative Boundaries Database for Asia	http://www.grid.unep.ch/data/grid/human.html	2.5’ or 0.04167 degree ≅ 3.5 km in average	Grid cells	Population counts	1995
Vulnerability factors	UNEP/GRID : GEO-3 Data portal	http://geo3.grid.unep.ch/	560 km (average of square root of country areas)	Polygons (country)	23 socio-economic variables	1980-2000
	UNDP : Human Development Report	http://www.undp.org/		Country	Human Development Index (HDI)	1995-2000

2 COMPUTATION OF PHYSICAL EXPOSURE TO DROUGHT

2.1 *Identification of drought* (explanations from the author: Brad Lyon)

The data used in the analysis consists of gridded monthly precipitation for the globe for the period 1979-2001. This dataset is based on a blend of surface station observations and precipitation estimates based on satellite observations. Further details of the data are described at the end of this section.

The first step in assessing the exposure to meteorological drought was to compute, for each calendar month, the median precipitation for all grid points between the latitudes of 60S and 70N over the base period 1979-2001 (the 23-yr. period for which the data was available). Next, for each gridpoint, the percent of the long-term median precipitation was computed for every month over the period Jan 1980 to Dec 2000. For a given month, gridpoints with a long-term median precipitation of less than 0.25 mm/day were excluded from the analysis. Such low median precipitation amounts can occur either during the "*dry season*" at a given location or in desert regions and in both cases our definition of drought does not apply. Finally, a drought "event" was defined as having occurred when the percent of median precipitation was at or below a given threshold for at least 3 consecutive months. The different thresholds considered were 50%, 75% and 90% of the long-term median precipitation with the lowest percentage indicative of the most severe drought according to this method. The total number of events over the period 1980-2000 were thus determined for each gridpoint and the results plotted on global maps.

2.2 Computation of physical exposure

Using the IRI/Columbia University data set, the physical exposure was estimated by multiplying the frequency of hazard by the population living in the exposed area. The events were identified using different measurements based on severity and duration as described in Table 6. The frequency was then obtained by dividing the number of events from the 6 following cases by 21 years, thus providing an average frequency of events per year.

Table 6 Measurements of drought

Duration	**Severity**
3 months	90% of precipitation (-10%)
3 months	75% of precipitation (-25%)
3 months	50% of precipitation (-50%)
6 months	90% of precipitation (-10%)
6 months	75% of precipitation (-25%)
6 months	50% of precipitation (-50%)

The physical exposure was computed as in Equation 1 for each of the drought's type:

Equation 1: Computation of physical exposure

$$PhExp_{nat} = \Sigma F_i \cdot Pop_i$$

Where:

$PhExp_{nat}$ is the physical exposure at national level (spatial unit)
F_i is the annual frequency of a specific magnitude event in one spatial unit
Pop_i is the total population living in the spatial unit

3 STATISTICAL ANALYSIS

3.1 Introduction and methods used

The aim of the present study is the description of statistical links between impacts of droughts on countries in terms of human losses in relation with the number of people exposed and socio-economical data for those countries to approximate vulnerability. This was performed globaly and over a period of 21 years ranging from 1980 to 2001.

Impact Data

As explained at the beginning of the report, the data were extracted from CRED database by merging famine and drought database. Only the casualties (killed) were considered for reason already exposed in GRAVITY-II. The data were then aggregated over the concerned period for each country.

Socio-economical Data

The choice of the socio-economical indicators was made by UNDP/BCPR after an extensive consultation of drought expert. The choice was limited to publicly available data, so that a certain number of recommendations could not be taken into account.

Table 7: Variable introduced in the statistical analysis

Name of variable	**Abbreviation**
Global Domestic Product per capita	GDPcap
Human Development Index	HDI
Human Poverty Index	HPI
Under five years old mortality rate	U5MORT
Percentage of agriculture's dependency for GDP	GDP_{AGR}
Percentage of labor force in agricultural sector	AGREMP
An index of soil degradation	GLASOD
Percentage of population having access to improved water supply in rural area	WAT_{RUR}
urban area	WAT_{URB}
globally	WAT_{TOT}

Transformations of data

Referring to the methodology used in GRAVITY-II, a multiplicative model expressing "Killed" as a product of the other variables with certain exponents was tested. For that purpose, logarithms have been computed to provide an additive formula and significant variables as well as their exponents are searched by the use of statistical regressions. Natural logarithms of all variables described above have been computed (extension "_ln"). Remark that countries for which "Killed" is zero are excluded as was the case in other GRAVITY studies (some countries might not report casualties, whereas they are known to suffer from drought. Then logarithms can be computed. It has also been tried a logistic transformation before taking logarithms for variables expressed in percentage. The study should determine, for each significant variable, whether the logistic transformation is an improvement or not.

3.2 Preliminary analysis

Correlations

The different variables are obviously not statistically independent. Since one of the three components used to derive HDI is the GDP, GDPcap is then highly correlated (0.878) as seen on Table 8. However, GLASOD and GDPcap are two independent variables (-0.034). A low correlation and hence high p-value is better for a statistical analysis. The high correlation between two variables will be taken into account while discussing the results.

Table 8 Pearson Correlations and p-Value between socio-economical parameters

	GDP_{CAP} $^{(ln)}$	HDI $^{(ln)}$	GLASOD	$^{(\%)}U5_{MORT}$	$^{(\%)}AGR_{EMP}$	GDP_{AGR}	$^{(\%)}WAT_{RUR}$	$^{(\%)}WAT_{URB}$	HPI$^{(ln)}$
HDI $^{(ln)}$	0,878								
p-Value	*0,000*								
GLASOD	-0,034	0,184							
p-Value	*0,907*	*0,511*							
$^{(\%)}U5_{MORT}$	-0,755	-0,912	-0,299						
p-Value	*0,000*	*0,000*	*0,244*						
$^{(\%)}AGR_{EMP}$	-0,282	-0,353	-0,423	0,311					
p-Value	*0,273*	*0,150*	*0,091*	*0,182*					
GDP_{AGR}	-0,135	-0,008	-0,230	0,115	0,560				
p-Value	*0,606*	*0,975*	*0,391*	*0,640*	*0,013*				
$^{(\%)}WAT_{RUR}$	0,485	0,506	0,056	-0,519	-0,345	-0,295			
p-Value	*0,057*	*0,038*	*0,838*	*0,027*	*0,161*	*0,251*			
$^{(\%)}WAT_{URB}$	0,248	0,437	0,091	-0,455	-0,342	-0,028	0,435		
p-Value	*0,355*	*0,079*	*0,737*	*0,058*	*0,164*	*0,915*	*0,071*		
$^{(\%)}WAT_{TOT}$	0,593	0,649	0,042	-0,639	-0,399	-0,224	0,934	0,658	
p-Value	*0,015*	*0,005*	*0,876*	*0,004*	*0,101*	*0,388*	*0,000*	*0,003*	
HPI $^{(ln)}$	-0,806	-0,938	-0,265	0,844	0,383	0,180	-0,413	-0,437	-0,572
p-Value	*0,000*	*0,000*	*0,320*	*0,000*	*0,106*	*0,475*	*0,089*	*0,070*	*0,013*

$^{(Ln)}$ = logarithm of the variable
$^{(\%)}$ = value expressed in percentage
See Table 7, p.6 for acronyms and abbreviations.

High correlation can be seen between "GDPcap" and "HDI", "HDI" and "$U5_{MORT}$", and "HDI" and "HPI". Those four variables being very dependent cannot be kept together for the regression. A selection is needed and different attempts with each of them were necessary to determine the optimum selection. Nevertheless, when the choice has been done, it doesn't mean that variables left are not significant. It only means that a choice was performed and that one variable in a set of variables expresses the same idea (such as e.g. the level of development). Correlation between the different variables of water supply were also observed and a correlation between water supply and development variables as seen in Table 8.

Selection

Although twenty countries reported casualties, only eleven of them include all the variables. Some doubts existed on several countries with zero reported casualties. This will be further discussed in the chapter “results”.

Regression concerning different sets of variables have been tested, and the most significant sets of variables are couples formed by one of the physical exposures (PhExp) and “WAT_{TOT}”. The corresponding R^2 are good, p-values are very low and fast residual analysis shows no abnormality and no particular structure, thus validating those regressions. After preliminary analysis performed on 11 countries, some indicators were rejected allowing a larger group of countries to be selected.

4 RESULTS AND DISCUSSION

4.1 Main Analysis

Selection of countries

Out of twenty countries with reported casualties from drought, all had physical exposure, except for the layer "Phexp6_50_ln" (which correspond to rather rare events). The absence of records for the variable "WAT_{TOT}" was responsible for the exclusion of two countries: Somalia and Swaziland. High incertitude on the same value lead to the rejection of North Korea. Eccentric values for both Sudan and Mozambique suggested a more complex origin of deaths, which could be resulting from the conflicts having taken place in those countries. Table 9 summarise the reason why the five countries were rejected from the analysis, while Table 10 lists the remaining countries selected for the statistic analysis.

Table 9: Reason for rejection of countries for the analysis

Countries rejected	**Reason**
Swaziland	WAT_{TOT} value inexistent
Somalia	WAT_{TOT} value inexistent
North Korea	Reported WAT_{TOT} = 100% (highly doubtful)
Sudan	Eccentric values, suggesting other explanation for casualties
Mozambique	Eccentric values, suggesting other explanation for casualties

Table 10: List of countries considered for the model

15 Countries selected				
Brazil	Burundi	Chad	China	Ethiopia
Guinea	India	Indonesia	Kenya	Madagascar
Mauritania	Pakistan	Papua New Guinea	Philippines	Uganda

For the variable "WATTOT_ln" and the (log of) physical exposures 3_50, 3_75, 3_90, 6_50, 6_75, 6_90, corresponding R-squares are: 0.78, 0.74, 0.75, 0.28, 0.55, 0.60. It shows a great difference between 3-months layers and 6-months layers. One can notice that this difference becomes very small if China and India are taken apart, which could be related to climatic reasons: in certain countries, there could have been dramatic droughts of less than 6 months that are not handled by 6-months physical exposure. That fact suggests that a more complex definition of droughts, including the climate (for example in a raster way), should be more appropriate and could give better results. Concerning the three 3-months layers, the difference between them is not very significant, although in different regressions "Phexp3_50_ln" gives the better R-square. The same for the difference between "WATTOT_ln" and "WATTOT_lnb" which give similar results, with a slighlty better R-square for "WATTOT_ln". It was then decided to use the two variables "Phexp3_50_ln" and "WATTOT_ln" in the sequel. The result of the linear regression is then the following:

Equation 2: Risk regression for drought

$$\text{Ln Killed} = 14{,}4 + 1{,}26 \text{ Ln PHexp3\_50} - 7{,}58 \text{ Ln Water}_{TOT}$$

Where:

PHEXP3_50 : nb of people exposed per year to droughts ; a drought is defined as a period of at least three months less or equal to 50% of the average precipitation level (IRI, CIESIN/IFPRI/WRI)

$Water_{TOT}$: % of population with access to improved water supply (WHO/UNICEF)

Table 11: Exponent and p-value for drought multiple regression

Predictor	Coef	SE Coef	T	p-value[1]
Constant	14,390	3,411	4,22	0.001
PHexp3_5	1,2622	0,2268	5,57	0,000
WATTOT_l	-7,578	1,077	-7,03	0,000

S = 1,345 R-Sq = 0.812 R-Sq(adj) = 0.78

4.2 Discussion

The small p-values observed suggest a relevant selection of the indicators among the list of available datasets. It is to be noted that the high coefficient for WATTOT_ln (-7.578) denotes a strong sensibility to the quality of the data. This implies that even a change of 1% in the percentage of total access to water will induce significant change in the results, especially for small values (where small changes have bigger influence in proportion).

If the model allows the selection of socio-economic parameters indicating the vulnerability of the population, this model cannot be used for predictive purpose. Some inconsistencies were depicted in the data that require verification.

The two indicators selected through the statistical analysis are not surprising. Physical exposure summarise the frequency of hazard and the element at risk (here the population) while the the percentage of population with access to improved water supply is an obvious indicator of vulnerability to drought. This could obviously be derived through common sense (population with good water supply less suffer from drought is not surprising). However, the fact that it was selected and that a strong correlation could be established ($R^2 = 0.81$) between independent datasets such as level of precipitation, population, casualties from drought and access to water, assess the solidity of the method as well as the reliability of these datasets for such scale.

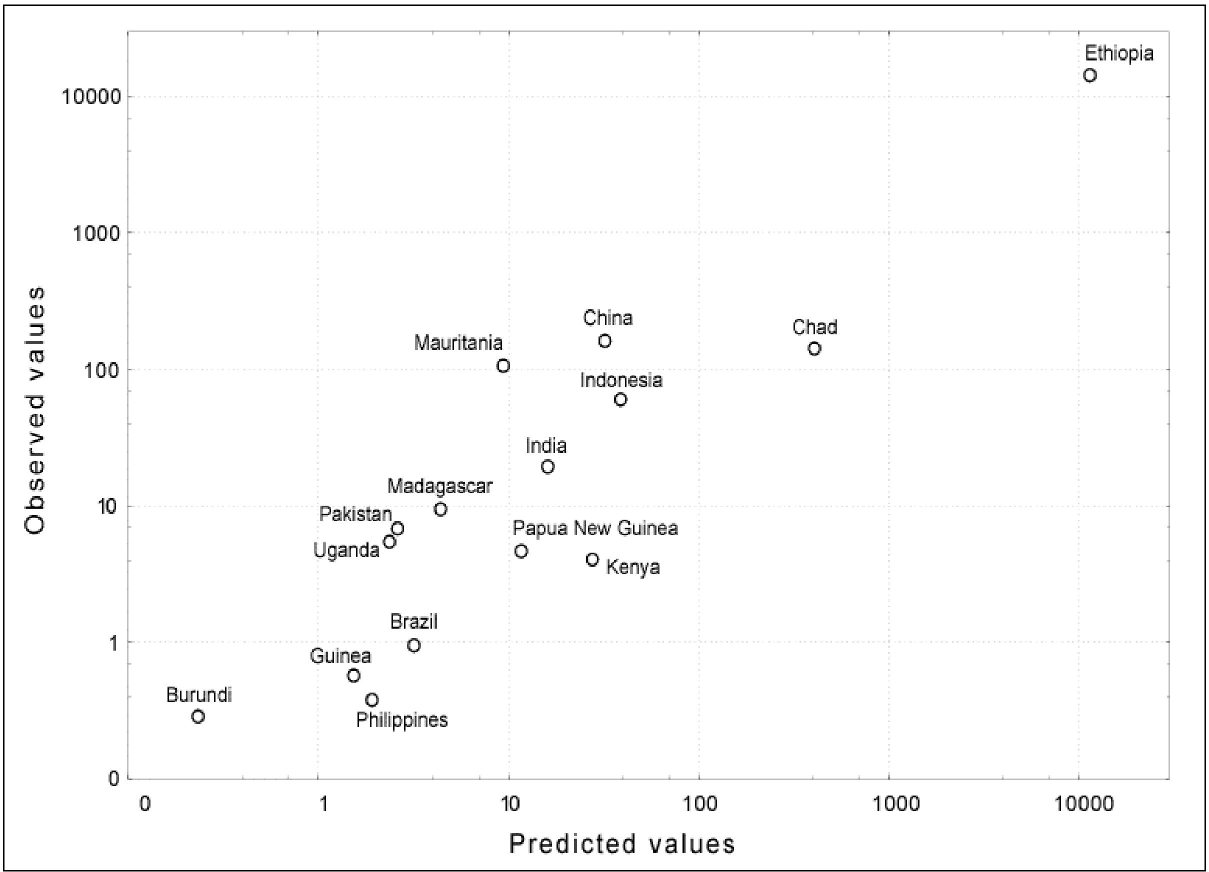
Given the level of precision of the data, such match is much higher than originally expected.

The Figure 1 shows the distribution (on a logarithmic scale) of expected casualties from drought and as predicted from the model. A clear regression can be drawn. It is true that if Ethiopia is removed the correlation will fall to a mere ($R^2 = 0.6$), however the off set and the slope of the regression line do not change significantly thus assessing the robustness of the model.

A residual analysis and Anderson-Darling normality test both validated the regression (see Appendixes, p.25).

[1] In broad terms, a p-value smaller than 0.05, shows the significance of the selected indicator, however this should not be used blindly.

Figure 1: Predicted versus observed casualties for droughts (killed/year 1980-2000)



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 is decreasing as the percentage of population when improved water supply is growing. Remember that 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 under five mortality rate ($U5_{MORT}$) and Human Development Index (HDI).

There were some concerns about some features reported in CRED. Some countries with large physical exposure did not reported any killed (see Table 12, p.12 for details). This could be for different reason: either the vulnerability is null (or extremely low) e.g. USA, Australia or the number of reported killed from food insecurity is placed under conflict (e.g. Iraq, Angola,…) for other countries a further inquiries might be necessary.

The Table 13 (p.13) provides a list of countries presenting both highest killed per year and in percentage of the population. Using the features provided and depending on the consideration of risk indicators. Categories of countries affected by drought on different priorities could be derived. For example, countries with high losses and countries with high losses in proportion of the population, countries with average losses but high in proportion of the exposed population (high vulnerability). If criterion are provided, each category could be defined according to UNDP/BCPR specific priorities for intervention and corresponding to specific program of prevention.

Table 12: Countries without reported killed, with high event/year, exposure
(in top ten of either event/year or physical exposure)

Countries	Events/year	Physical exposure	Access to water
USA	0.29	10,575,287	100
Vietnam	0.19	6,992,117	52
Nigeria	0.10	6,710,446	53
Mexico	0.29	6,514,208	85
Iraq	0.05	4,570,313	85
Sri Lanka	0.29	2,839,534	75
Ecuador	0.10	2,116,246	71
United Republic of Tanzania	0.38	1,501,349	52
Cuba	0.24	1,485,612	95
Australia	0.33	1,323,787	100
Senegal	0.24	936,639	75
Jordan	0.10	882,733	97
Angola	0.29	531,613	38
Lao People's Democratic Republic	0.29	331,499	90
Niger	0.33	267,619	56
Bolivia	0.29	258,026	77
Namibia	0.29	132,704	75
Gambia	0.24	104,721	62
Djibouti	0.29	75,763	100
Botswana	0.33	15,891	95

Table 13. Vulnerability to droughts (countries with killed)

Country	Event/year	K/Year	K/Inh	Physical exposure	Vul. Prox.	$^{(\%)}WAT_{TOT}$
Dem.People's Rep. of Korea	0.10	12,857.1	579.4	763,17	16,846.9	100*
Ethiopia	0.57	14,303.2	286.2	2,756,27	5,189.3	23
Sudan	0.48	7,142.9	294.1	2,478,87	2,881.5	71
Mozambique	0.43	4,764.3	357.1	878,64	5,422.4	60
Mauritania	0.33	106.8	57.9	172,16	620.4	37
Chad	0.33	142.9	27.9	514,05	277.9	27
Swaziland	0.33	23.8	31.6			No data
Somalia	0.24	29.6	4.1	726,18	40.7	No data
China	0.86	161.9	0.1	26,855,21	6.0	73
Indonesia	0.29	60.3	0.3	29,982,87	2.0	73
Madagascar	0.24	9.5	0.8	324,98	29.3	46
Papua New Guinea	0.14	4.7	1.2	436,92	10.7	42
Uganda	0.29	5.5	0.3	242,37	22.6	47
India	0.38	19.5	0.0	33,701,76	0.6	83
Pakistan	0.05	6.8	0.0	9,811,89	0.7	86
Kenya	0.29	4.0	0.2	1,219,32	3.3	45
Guinea	0.14	0.6	0.1	161,65	3.5	47
Brazil	0.43	1.0	0.0	10,345,73	0.1	85
Burundi	0.10	0.3	0.0	269,94	1.1	65
Philippines	0.24	0.4	0.0	8,240,94	0.1	87

* Highly improbable

4.3 Maps

Method of classification

The number of classes and method for classifying the maps were chosen according to several criteria such as the precision of the data, the number and weight of error the correlation between model and observed values. According to these tests the number of five classes based on an equal interval subdivision method, was minimising the error weights and optimising the representation.

Categories

The precision and quality of the data does not allow the ranking of countries. However, for the risk component, results indicate a possibility to provide five classes of countries. As already stated in GRAVITY 2, a subjective – political – choice has to be made in order to choose from the different possibilities of computing risk (i.e. killed, killed per million inhabitant,…) such decision belongs to UNDP. The UNDP aims to provide categories of countries taking into account both risk and disaster reduction measures.

The following maps depict distribution of physical exposure, vulnerability (computed as killed divided by physical exposure) and risk.

The map in Figure 2, spatially depicts where main differences exist between number of casualties and exposure. The main interest of this map might rely on identifying problems that are common to a large region (such as sub-Saharan countries, Chad, Sudan, Ethiopia) and problem that are only affecting a single country (e.g. North Korea, Mozambique). This might help defining program accordingly. Figure 4 highlights groups of countries with different situation. For instance, even though India, China and Indonesia have the highest physical exposure, the number of casualties remains average, thus implying a low vulnerability to drought. On the other extreme, Sudan, Ethiopia, North Korea and Mozambique are presenting a very high vulnerability highlighting either inappropriate governance practices or situations of conflicts. If a diagonal line was drawn from bottom left to top right. Countries below this line would be dealing better than average with the drought issue, whereas countries above the line would need to improve their strategies.

These are only some examples of products that could help highlighting the vulnerability to drought. Numerous types graphical, tables and maps could be derived from these features to better illustrate patterns and distribution of risk, physical exposure and vulnerability. This might constitutes the next development in this field in the near future.

Figure 2: Map of Vulnerability and Physical Exposure to Droughts

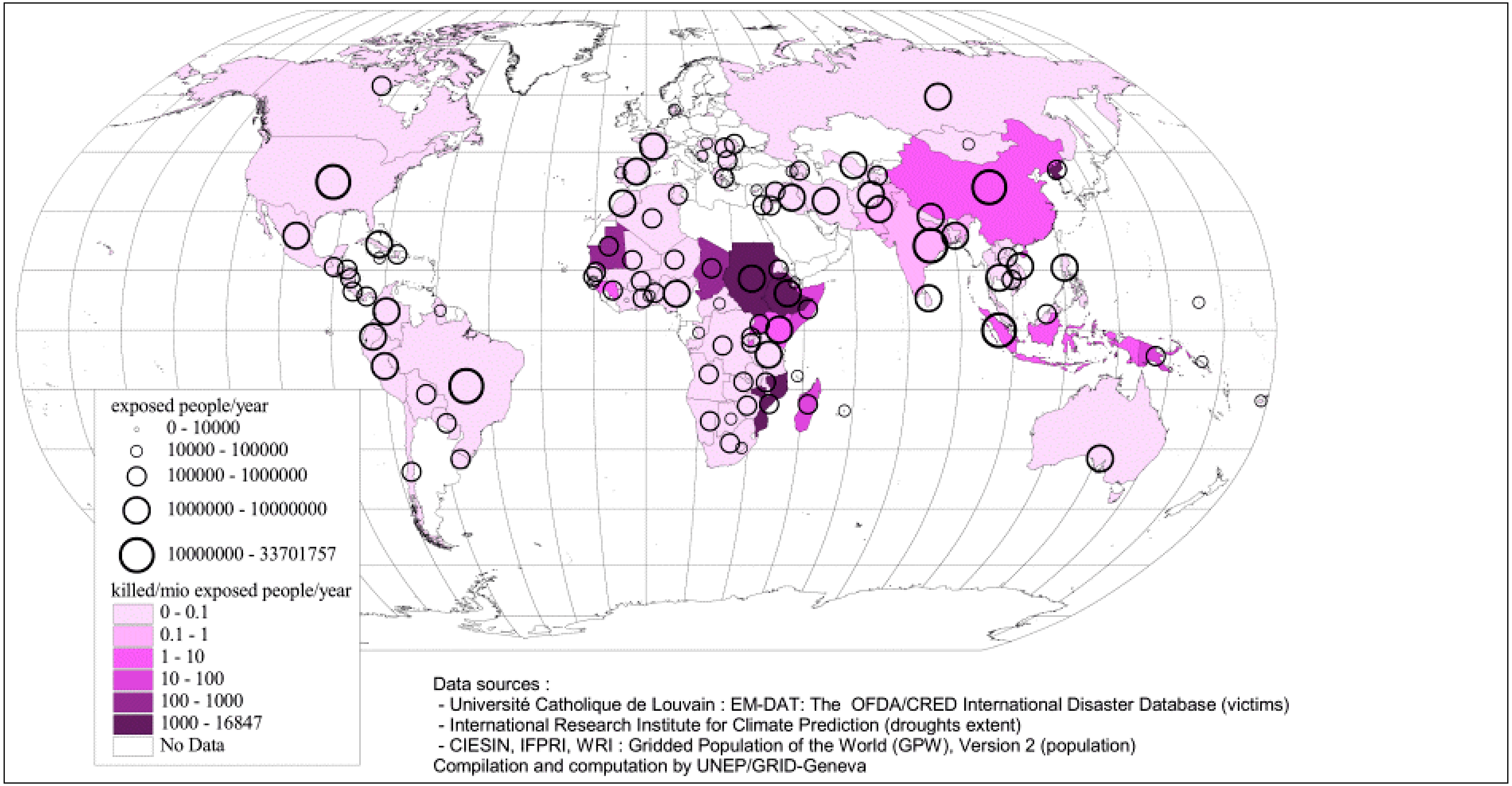


Figure 3: Map of Risk to Droughts

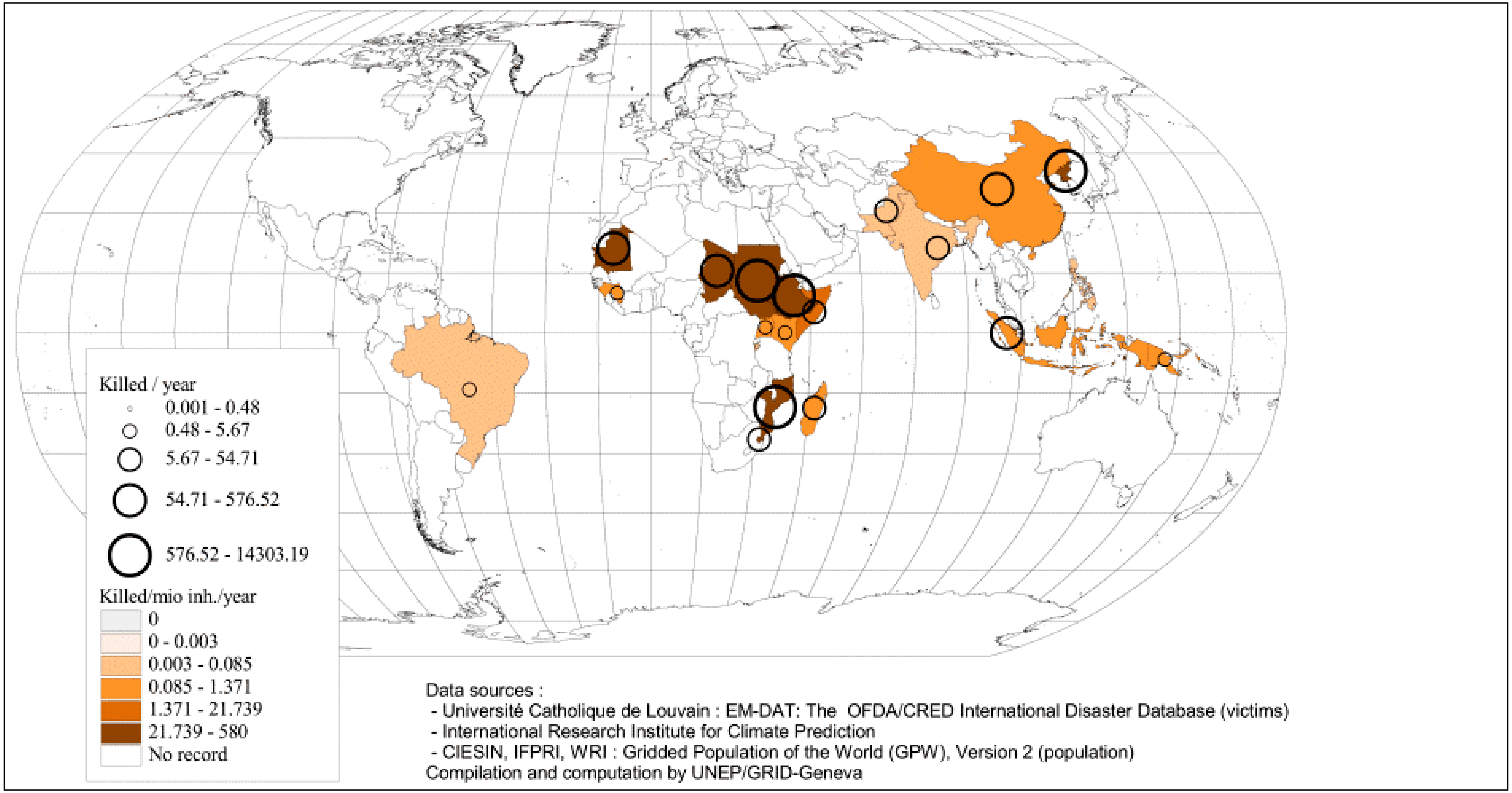
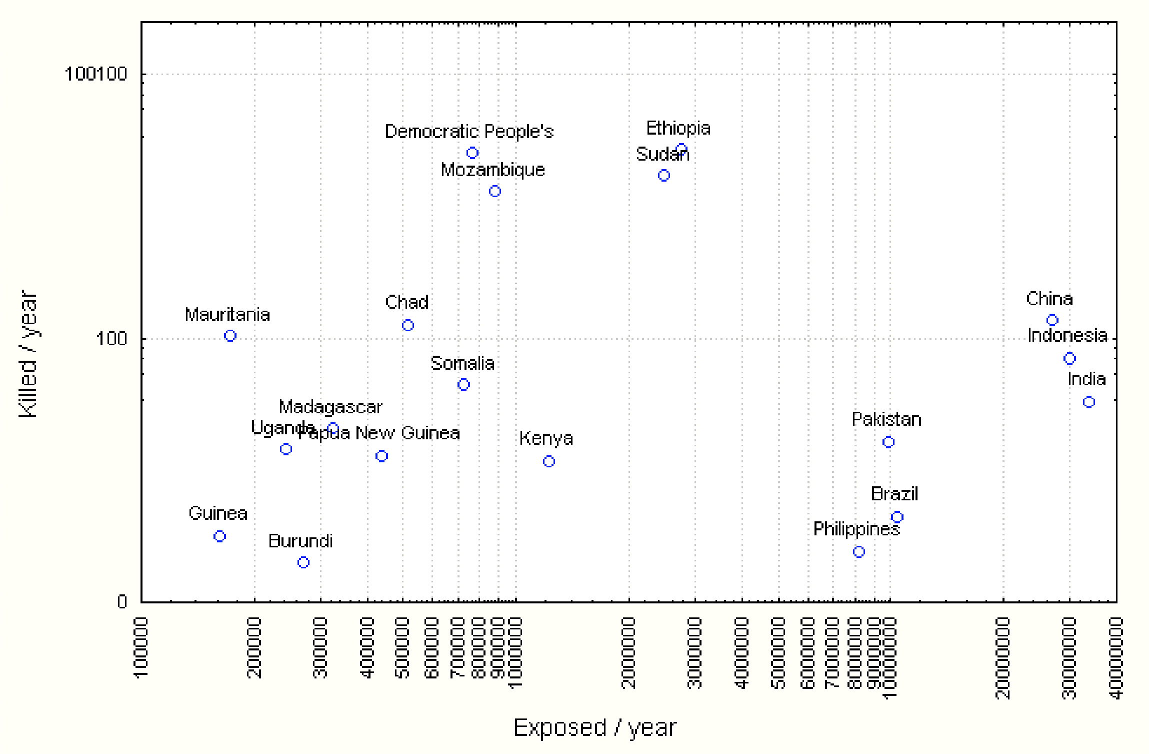


Figure 4 Scatter plot of physical exposure versus killed per year for droughts



5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Comments

In terms of identifying vulnerability parameters to drought, the method already applied to other types of hazard as reported in GRAVITY-II appeared to be successful when applied to drought. The variables selected (physical exposure and total access to water) is not original and might lack of surprise, at least it is coherent with common sense. Moreover, it should be kept in mind that this variable is correlated with HDI and under five mortality rate. So these indicators of human development are also represented through this regression. The results of the study would probably gain in interest once data are available on victims from AIDS, corruption or if mixed with year of conflicts. Type of governance and conflicts are suspected to be significant parameters leading to higher vulnerability as North Korea, Mozambique and Sudan were rejected by the model, meaning that the retain variables were not appropriate to reflect the situation of these countries.

The very high sensitivity to the data of the drought model confirms that the equation should not be used for predictive applications. Three main problems will occur otherwise: firstly the countries with no data on total access to water will not be included. Secondly countries with inappropriate or inexact feature for total access to water will be ranked with great discrepancies (especially those with low values because of proportionality as discussed in 4.2, p.10). Finally, countries with casualties mostly due to conflicts and inappropriate governance will not be represented in an relevant way. The model is appropriate to select vulnerability parameters and to ensure the quality of both the method for drought estimation and data in CRED. At this point ranking or grouping countries using the model is not appropriate. This is still early days and all sort of effort in data access and understanding of the phenomenon.

The remaining issue consists on the countries without reported casualties, if some of them concern countries with low vulnerability others need further verification. As discussed in the results, it was suspected that the casualties of some countries were reported under conflicts in CRED. The issue is complex: to what extent the number of casualties resulting from food insecurity are due to exposition to physical drought and what percentage is due to conflict situation. In some countries food shortage is known to have been used as a weapon, in others the roads to dispatch food were too insecure leading to food shortage in some regions.

All in all, the steps achieved have filled a gap as no method or database was available on drought. It is still a first step and leave place to improvements. It is hoped that this will encourage new developments in this field in order to improve the method, the data, the understanding of risk and vulnerability and at the end, help aid organisation to assist population in need in a more efficient way.

5.2 Improvements

Socio-economical variables

Results delineate that global data sets can still be improved both in terms of precision and completeness, however they are already allowing the comparison of countries. Other indicators such as corruption index (transparencies) or political indicators would be interesting to test in the model, when all the countries will be available. It was surprising that indicators such as the number of physicians, the number of hospital beds or even the country dept service is not completed world-wide. Efforts on compilation are still needed. Tremendous amount of work was involved (by GEO3 team) to verify and complete the data. Units are not always accurate.

Drought

It might be interesting to test other precipitation data sets with higher spatial resolution, although the resolution did not seem to be causing so much problem. The use of geo-climatic zones might be useful in order to take into account the usual climate of a specific area. Indeed a drop of 50% precipitation might not have the same consequence on a humid climate as compared to a semi-arid area. The use of the Global Humidity Index (from UNEP/GRID UEA/CRU) might help in differentiate these zones.

5.3 Recommendations

Further improvements in the model can be performed:

The case of small islands and archipelagos

Small islands and archipelagos are causing problem. In some cases they were too small to be considered by the GIS automated algorithms. This was typically the case for the population and even more for the precipitation. The raster information layer for the population can not be used to extract the population of small islands. For single island countries, the problem might be overcome by using the population of the country, but for the others this was not possible. Indeed, when superimposing cyclone tracks on top of archipelago, the population is needed for each island. A manual correction is needed, but could not be performed due to the time frame of the study.

The compilation of socio-economical parameters was also not complete for the islands. This could probably be improved by contacting SOPAC.

For all these reasons, the case of small islands and archipelagos would need a separate study and intuitively, the vulnerability for isolated countries might be different than other connected countries as seen on previous GRAVITY report.

Extending to other hazards

a. Tsunamis and Landslides

Some countries are not well represented by the model, because they are affected by hazards which were not of global significance. This is the case of Papua New Guinea and Ecuador, which are affected by tsunamis (respectively 67.8 and 14.3% of national casualties); landslides are also causing significant impact in Indonesia (13,88%), Peru (33%) and Ecuador (10.2%). As a result, the global risk is under evaluated for these countries.

b. Epidemics

This is more a health angle and should probably be taken care of by the World Health Organisation (WHO). However, the appropriate sanitation, access to safe water, number of physicians per inhabitants and other health infrastructure are also significant parameters of development. Data on epidemics are now starting to be available. Epidemics is representing a significant amount of casualties and AIDS is definitely impacting developing societies especially (but not only) in Africa.

c. Conflicts

The case of conflicts although much more politically difficult to approach is probably also highly correlated to human vulnerability. Results from a statistical analysis would be extremely interesting.

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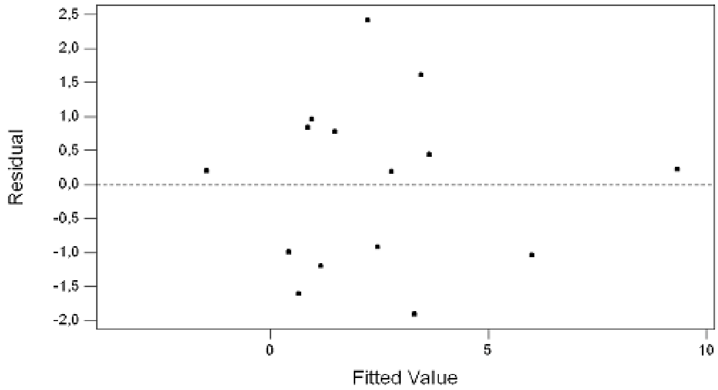
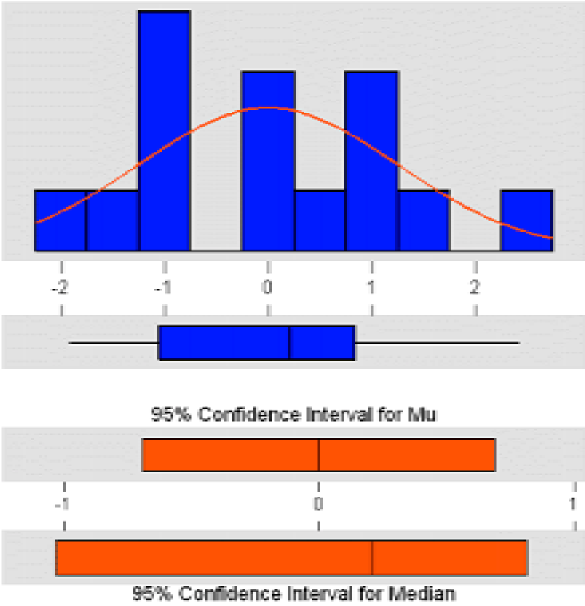
Appendixes

Appendix 1: Residual versus the fitted value



Appendix 2: Descriptive statistics



Variable: RESI19

Anderson-Darling Normality Test

A-Squared:	0,324
P-Value:	0,490
Mean	-0,00000
StDev	1,24565
Variance	1,55165
Skewness	0,203377
Kurtosis	-6,4E-01
N	15
Minimum	-1,91682
1st Quartile	-1,04932
Median	0,20675
3rd Quartile	0,83880
Maximum	2,42828

95% Confidence Interval for Mu

-0,68982	0,68982

95% Confidence Interval for Sigma

0,91198	1,96452

95% Confidence Interval for Median

-1,02754	0,81542