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How useful and reliable are disaster databases in the context of climate and global change? A comparative case study analysis in Peru

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Abstract

Loss and damage caused by weather and climate related disasters have increased over the past decades, and growing exposure and wealth have been identified as main drivers of this increase. Disaster databases are a primary tool for the analysis of disaster characteristics and trends at global or national scales, and support disaster risk reduction and climate change adaptation. However, the quality, consistency and completeness of different disaster databases are highly variable. Even though such variation critically influences the outcome of any study, comparative analyses of different disaster databases are still rare to date. Furthermore, there is an unequal geographic distribution of current disaster trend studies, with developing countries being under-represented.

Here, we analyze three different disaster databases for the developing country context of Peru; a global database (EM-DAT), a regional Latin American (DesInventar) and a national database (SINPAD). The analysis is performed across three dimensions, (1) spatial scales, from local to regional (provincial) and national scale; (2) time scales, from single events to decadal trends; and (3) disaster categories and metrics, including the number of disaster occurrence, and damage metrics such as people killed and affected.

Results show limited changes in disaster occurrence in the Cusco and Apurímac regions in southern Peru over the past four decades, but strong trends in people affected at the national scale. We furthermore found large variations of the disaster parameters studied over different spatial and temporal scales, depending on the disaster database analyzed. We conclude and recommend that the type, method and source of documentation should be carefully evaluated for any analysis of disaster databases; reporting criteria should be improved and documentation efforts strengthened.

1 Introduction

Losses due to weather- and climate-related disasters have increased over the past decades (Barthel and Neumayer, 2012; IPCC, 2012), amounting to a total of about 1.42 million people killed and over 900 billion USD financial loss globally between 1980 and 2007 (WMO, 2013). In the context of climate change there is concern that losses will further increase in the future (IPCC, 2012; ISDR, 2009). Within the United Nations Framework Convention on Climate Change (UNFCCC) a working programme on loss and damage has been initiated and was strongly pushed during the last international climate negotiations. The UNFCCC and the main international policy framework for disaster risk reduction, the Hyogo Framework for Action, call on data and information on disaster events and losses to effectively develop policies and actions to manage and reduce risks. Disaster databases are a primary source and tool to store and manage a range of data on disasters.

Among the most well known and widely used disaster databases with global coverage are the Emergency Events Database (EM-DAT), maintained by the World Health Organization (WHO) Collaborating Center for Research on Epidemiology of Disasters (CRED) in Brussels which is publicly available and has been used in several scientific studies (e.g. Barredo, 2009; Peduzzi and Herold, 2005; Peduzzi et al., 2009). NatCatSERVICE from the reinsurance company MunichRe is the largest database but is not open access. SwissRe's sigma is another major global disaster database and likewise not open access.

In the context of global and climate change, research has increasingly started to analyze changes in the occurrence of disaster events and losses. It should thereby be noted that disasters are the result of the physical impact of a climatic event, and the exposure and vulnerability of the system affected (Cutter and Finch, 2008; Cutter et al., 2008; Huggel et al., 2013; Wisner et al., 2004). So far, growing exposure of people and assets, and increasing wealth, have been identified as the main drivers of change in disaster losses (Bouwer, 2011; IPCC, 2012). Many studies thereby focused on a global scale or on a few selected developed countries (Barredo, 2010; Neumayer and Barthel, 2011; Pielke Jr. et al., 2008; Schmidt et al., 2010).

While the identification of the main drivers of increasing losses represents a robust result of global relevance, there are a number of issues in this context that have not yet been addressed, or only in a limited way.

First, there is an unequal geographic distribution of high-quality databases and related analyses (Gall et al., 2009). Studies on changes of disaster events and losses in developing countries are much more rare than in developed countries such as in Europe or the United States. This is of particular concern because developing countries typically have a higher vulnerability to weather and climate related extreme events (Adger et al., 2003; Füssel, 2010). Furthermore, there is even less information available at sub-national scales ("Regiones" level in Peru) in developing countries. To some degree this deficiency is related to the availability and quality of disaster databases in those countries.

Second, and directly related to the aforementioned statement, there is insufficient research into a comparison of different disaster databases, related results and implications of the respective analysis (Gall et al., 2009). The form and methods how data and information are observed, reported, collected and stored in the databases critically influences the outcome of any analysis (Kron et al., 2012). There exists no international consensus as to how disaster data are compiled (CRED, 2013). Consistency in data collection over time is an additional issue that is of major importance for trend analysis but often very difficult to track and check. In developing countries with often less institutional stability consistency over time is of particular concern. This is corroborated by a recent comparative review of country-level and regional disaster loss and damage databases by the United Nations Development Programme (UNDP) which, for instance, found that more than 50 % of the databases analyzed contain gaps with no entries for specific years, or only 17 % of the databases have used a quality control procedure (UNDP, 2013). The limited quality (control) of many databases also questions the reliability of the results based on analysis of the databases. This shortcoming is particularly important in view of the role databases play, or are foreseen to play, for disaster risk reduction policies and actions.

Here, we address the aforementioned limitations by (1) exploring the use of disaster databases for analyzing spatio-temporal changes in the occurrence of weather and climate related extreme events and disasters at sub-national scales in a developing country context in the Andes of Peru; and by (2) carrying out a straightforward comparative analysis of two and more databases for the same time periods and spatial scales (national and sub-national). For this purpose we use a global database (EM-DAT), a regional Latin American (DesInventar) and a national database (SINPAD) for Peru. The spatial scales involved are mainly at the level of "Regiones" and the national scale, while the time scales include decadal scale analysis as well as single extreme events and disasters. We specifically investigate the value of different disaster databases for the heavy rainfall and flood disasters in early 2010 in Cusco, Peru, and put this disaster in the associated climatic context. Although we try to shed some light on the underlying causes of the observed disaster patterns at the national scale, such an analysis is not a primary focus of this paper, mainly due to limited availability of corresponding data, in particular on the sub-national scale.

The paper is structured as follows: we first introduce the study regions, the disaster and climatic data used along with a definition of extreme events considered, and the methods applied. We then present the results of the spatio-temporal analysis of disaster changes over the past four decades in the "Regiones" of Cusco and Apurímac, followed by a short analysis of the national scale comparison of different databases. Finally we analyze the disaster databases and climatic conditions of the 2010 Cusco floods.

2 Study region

A main focus of this study lies on two administrative regions ("Regiones") in southern Peru, Cusco and Apurímac (Fig. 1). Peru distinguishes between the administrative spatial units of “Regiones”, “Provincias” and “Distritos” where “Regiones” include “Provincias”, and “Provincias” include “Distritos”. To avoid any confusion with English terms we will use here the original Peruvian terms in Spanish. Cusco and Apurímac extend over an area of 72 000 and 21 000 km^2, respectively, from less than 300 m a.s.l. to over 6300 m a.s.l. A great share of the area is high Andean territory with elevations of 2500 m a.s.l. and above. Glacierized mountain ranges exist in the west and the center of the study region. The topographic, ecologic and climatologic diversity is high in the region. Vegetation and climate zones include warm and humid tropical lowland areas in northern Cusco, both warm-arid and warm-humid zones with extensive forests in medium elevations up to ca. 2500 m a.s.l., followed by a zone up to 3500 m a.s.l. that is cultivated with a variety of crops. The climate in this zone has distinct seasons: a dry winter and a wet summer. Frequent frosts occur above 3500 m a.s.l. but several crops are still cultivated. Grassland dominates the zone between 4000 and 4800 m a.s.l. while above 4800 m a.s.l. glaciers and perennial snow occur. In the Altiplano areas from about 3800 to 4800 m a.s.l. local people keep livestock such as cameloids (lamas, alpacas, vicuñas), sheep and cattle and to some extent cultivate potatoes, quinua, barley and other crops (Tapia, 1997). Many small population centers in the high Andes are isolated with poor infrastructure and education, social and health services, and subsistence farming dominates. The Altiplano area is characterized by high inter-annual climate variability, with climatic extremes posing notorious threats to the highly vulnerable population.

Larger urban centers exist at lower elevations of 2500 to 3500 m a.s.l., including the regional capital Cusco with about 0.5 million inhabitants. The population of the whole study region is 1.65 million. Main traffic and other infrastructure extend along a northwest – southeast corridor.

3 Data and methods

Disaster data used in this study are based on three disaster databases and inventories, from global, to regional and national level.

EM-DAT is a global disaster database and is maintained by the Center for Research on the Epidemiology of the Disasters (CRED), Université Catholique de Louvain, Belgium. EM-DAT is based on data from organizations of the United Nations, non-governmental organizations, insurance companies, scientific institutions and media (CRED, 2013). EM-DAT distinguishes between two generic categories of disasters (natural and technological), followed by several sub-groups including geophysical, meteorological, hydrological, climatological and biological disasters. Each of those subgroups is again divided into a number of disaster types (e.g. floods, landslides, avalanches, etc.). For each disaster reported information is provided as regards the date, people killed, injured, homeless or affected, and estimated damage (in USD), if available. At least one of the following criteria needs to be fulfilled to report a disaster in EM-DAT: (1) ten or more people reported killed, (2) one hundred or more people affected, (3) declaration of a state of emergency, or (4) call for international assistance.

DesInventar is a regional scale database and inventory system for a wide range of disasters, their characteristics and impacts (DesInventar, 2013). It includes information at the local, to national and regional level. It has its origin in the mid-1990's when information on small to medium-scale disasters was not available for the Andes region, and neither for Latin America. A group of scientists and experts from several institutions therefore formed the Network of Social Studies in the Prevention of Disasters in Latin America (La RED) which developed the concepts and methods for a disaster database based on existing newspaper, government and other reports for nine countries in Latin America, including the Andean countries. Nowadays, DesInventar has been expanded to some selected countries in Africa and Asia.

In the case of Peru DesInventar stores information on disaster events since 1970, exclusively based on reports in the Peruvian national newspaper "El Comercio". This newspaper is Lima based and therefore a certain local bias in documentation is reflected, with a relatively higher number of events reported from the capital region as compared to the “Regiones”.

The national scale disaster database used here is the Peruvian National Information System for the Prevention of Disasters (SINPAD) of the National Institute of Civil Defense (INDECI). SINPAD inventories events since 2001 at the level of the different administrative units of the country (“Regiones”, “Provincias”, “Distritos”) and according to categories such as number of people affected and casualties, infrastructure damage, surface area affected, etc. (INDECI, 2013).

Population data for the study region were retrieved from the Peruvian National Institute of Statistics and Informatics (INEI). The 2007 and earlier census provides demographic, economic and social data on the level of the administrative units of Peru. Digital elevation data was used from the Shuttle Radar Topography Mission (SRTM), providing information at a resolution of 90 m based on the February 2000 mission (Farr et al., 2007). A number of additional cartographic information, such as administrative boundaries, was also used.

For all three databases we extracted hydro-meteorological disasters. Since the disaster type and natural processes are not exactly the same in all databases we evaluated an appropriate common basis of categories and defined them as follows:

- cold spells,
- droughts,
- several precipitation events, including heavy precipitation, snow fall, hail,
- floods,
- several landslide types, including shallow landslides, debris flows, rock fall.

The analysis of trends in disaster occurrence across time and space was based on the DesInventar database to maintain the consistency over the four decades since

1970. DesInventar data was integrated into a Geographic Information System (ArcGIS, Environmental Systems Research Institute – ESRI) per disaster category, referenced to the respective administrative spatial unit ("Regiones", "Provincias" and "Distritos"). A geographically referenced database was thus developed which allowed us to retrieve spatio-temporal information. The disasters were analyzed per category, year, decade, and spatial unit. It should be noted, however, that a certain fraction of the original data from DesInventar did not have information on the exact location of the event, in some cases only indicating the name of the respective "Provincia" and "Region". These events needed to be excluded from the analysis.

Furthermore, it should be emphasized that disaster databases such as DesInventar and SINPAD do not consider whether a reported disaster resulted from a climatic extreme event as defined in statistical terms or not, i.e. a reported event may result from an extreme or non-extreme climatic event, where extreme is often defined as the 90th, 95th or 99th percentile of a statistical distribution (Beniston et al., 2007; IPCC, 2012; Trenberth et al., 2007). The criteria for inclusion of an event in DesInventar and SINPAD are not entirely clear but relate to impacts and possibly interruptions of functioning of social and economic systems as in other databases.

For the analysis of damage metrics (people killed and affected) we used DesInventar and EM-DAT at a national scale for Peru, and also over the past four decades. These two disaster databases have a different scope and documentation system where EM-DAT records many fewer events according to the more rigid criteria given above. DesInventar, on the other hand, does not provide damage metrics for each event recorded.

For a third comparative analysis we concentrated on a spatially and temporally much more constrained investigation than those at the sub-national and national scale and over several decades. We investigated the devastating 2010 heavy rainfall and flood disasters in Cusco. We used SINPAD and DesInventar data for the damage analysis. To gain a better understanding of this important extreme event we also looked at climatic data, in particular rainfall, to see how exceptional the 2010 floods were in terms of long-term climatology. Climatic data used was derived from a data portal developed in the framework of the Peruvian–Swiss Programme on Climate Change Adaptation (PACC), based on operational and historical data series of more than 100 stations of the Peruvian Meteorological and Hydrological Service (SENAMHI) for the "Regiones" of Cusco and Apurimac (Schwarb et al., 2011). This data portal facilitates the quality control of the meteorological data series and also allows the calculation of daily and monthly precipitation fields. Some of the stations in Cusco have been operational since about 1965 and allow a first estimation of extreme value occurrence, such as for heavy precipitation events. Here we concentrate on the long and homogenous data series of the station Granja Kcayra near the city of Cusco (13.56° S, 71.88° W, 3219 m a.s.l.; data record back to 1965) and the hourly values of Cusco airport (13.54° S, 71.94° W, 3249 m a.s.l.).

4 Results

4.1 Decadal-scale changes in disaster occurrence in Cusco and Apurímac

For Cusco the analysis of all categories as defined in Sect. 4 is based on DesInventar at the level of "Distritos" and reveals no clear pattern of change over four decades (Fig. 2). The northwestern and northeastern "Distritos" plus some central "Distritos" around the urban center of Cusco consistently show the highest number of events relative to the other "Distritos". No significant increase in disaster events can be noted over the period 1971–2009. During the decade of the 1980's a rather low number of events occurred while during the 1990's the number was highest.

This fluctuation in the frequency of events can also be seen in the analysis of the annual occurrence across the whole "Region" of Cusco (Fig. 3). Peak occurrence of events is documented in individual years such as 1994 and 2003. During the bulk of time period the number of events varies between about 10 and 40 events per year. After the record year 2003 the number of events decreased substantially. There is not any clear pattern visible as regards the different processes and hazard categories over time, either. For obvious reasons rainfall triggered hazards such as floods or landslides tend to cluster in individual years.

For Apurímac the picture is somewhat different: during the 1970's and 1980's the frequency of recorded disasters was low and only a limited number of "Distritos" have documented events (Fig. 4). In the 1990's the number of total events was clearly higher and new "Distritos" report disasters. During the first decade of the 21st century again a higher frequency of events was observed, along with a higher number of "Distritos" being affected by disasters. Most affected "Distritos" include Abancay (capital of the "Region" of Apurímac), Andahuaylas and Carhuasi. As can be seen in Fig. 1 population density is highest in those "Distritos".

Figure 5 furthermore indicates that the much higher number of registered events in the 2000's is primarily related to the first 5 years of the 21st century, with a very high peak in 2001. Reason for the high number of events in 2001 is predominantly heavy precipitation, with documented impacts in the form of rainfalls, floods and landslides/debris flows (Fig. 5). After this period the number of events per year drops again to levels observed during the last decades of the 20th century. With respect to individual disaster categories the analysis shows that cold spells only started to occur in the 2000s. Droughts are very rare except for a cluster of events in 1990. Overall, it is difficult to draw any clear conclusion about trends.

4.2 Decadal, national scale comparative disaster loss analysis

For the national scale comparative analysis for Peru we concentrated on the EM-DAT and DesInventar disaster databases and looked at changes in disaster losses over the past four decades (1970–2010, cf. Table 1). First of all, the number of events reported by DesInventar is roughly one order of magnitude larger than in EM-DAT. While the number of events in DesInventar reaches a peak in the 1990s, EM-DAT reports the highest number in the first decade of the 21st century. However, a clear trend in the number of reported disasters is hardly visible in either database, except for a significantly lower number for the 1970s in both databases. If we increase the temporal resolution of the analysis and look at annual disaster reports in EM-DAT we can recognize the year-to-year fluctuation of disasters, yet without any strong trend (Fig. 6). Figure 6 also indicates that EM-DAT is not feasible for sub-national scale analysis due to limited number of events reported (see highlighted Cusco and Apurímac).

The analysis of EM-DAT reveals significantly higher numbers of people killed and affected, respectively, as compared to DesInventar. This is striking given the enormous difference in reported events of the two databases.

As regards trends over the four decades, there is a relatively good correspondence between the two databases for people killed and affected. The number of people killed fluctuates in EM-DAT within a range of ±20 % from 1971 to 2010, while DesInventar shows a reduction of 35 % from the most recent decade compared to the 1970s. For people affected DesInventar and EM-DAT document a 7-fold and an almost 20-fold increase, respectively, over the four decades. Hence, while the number of people killed by weather and climate related extreme events remained approximately stable during the past 40 years in Peru, an enormous increase of people affected is reported. The absolute numbers between EM-DAT and DesInventar differ by about one order of magnitude for people affected but the strong increasing trend is likely a robust result.

4.3 Local scale single extreme event: the 2010 rainfall/floods in Cusco

The "Region" of Cusco was hit by a period of intense rainfall between January and March 2010. The highest rainfall intensities were recorded in late January 2010. The mainly affected "Provincias" include Anta, Calca, Quispicanchi, Urubamba and La Convención (see Fig. 1). Negative impacts were mainly due to floods, landslides or debris flows, triggered by the intense and long duration of precipitation. Floods were particularly devastating around 24/25 January 2010 in the Huatanay river downstream from the city of Cusco, and along the Urubamba valley in the Vilcanota river (Fig. 7). International media reports focused on the large-scale evacuation of tourists locked in the Machu Picchu area due to transportation lines cut by flood impacts.

Estimates of damage to people, infrastructure and service vary considerably. Analysis of data available through the INDECI disaster information system (SINPAD) indicates a total number of about 191 000 people affected, 206 injured and 17 killed between January and March 2010. Another source of INDECI, however, states a total of about 63 000 people affected, 382 injured and 26 killed in different “Provincias” of Cusco (INDECI, 2012). The large difference in terms of people affected could be due to cumulative counting for each event record in the first case, and an overview number in the second case.

Even larger differences in disaster metrics are revealed by an analysis of SINPAD and DesInventar databases for the extended period of rainfall/flood events in the “Region” of Cusco from January to March 2010. SINPAD provides multiple and detailed records of events with indication of the number of people affected while DesInventar only documents a fraction of these events without, or incomplete indication of people affected (Fig. 8).

INDECI reports furthermore document that almost 5000 residential houses were destroyed and more than 7300 were affected. Especially notable is that in the “Provincias” of Anta and Quispicanchi 34 % and 31 %, respectively, of all residential houses were destroyed. The total economic damage was estimated to about 635 million Nuevos Soles (ca. 220 million USD), with an approximate shared damage of 35 % on health, education and housing, 55 % on infrastructure (mainly transport and communication), and 8 % on tourism and agriculture (INDECI, 2012). Major indirect loss was caused by a break-down of tourist influx into Cusco due to disruption of access to Machu Picchu for several months.

To investigate whether, and to what extent the 2010 event was extraordinary in terms of climatic record we have first to consider that year-to-year variability in the Altiplano region of the Central Andes of Peru is high. For instance, for the station Granja Kcayra (near Cusco) the standard deviation of January precipitation sum is 46 mm (mean value: 146 mm), with a minimum value of 59 mm and a maximum value of 233 mm for the period 1965–2009. January 2010 was wetter than the long-term monthly maximum, amounting to a total of 269 mm, and thus represents a new record of January precipitation sum. The value is 2.67 standard deviations above the long-term mean (1965–2009).

Additional insight into the extreme 2010 event can be gained from the calculation of the extreme value statistics. Figure 9 shows the highest 1 day, 2 day and 5 day precipitation events for all years between 1965 and 2011. The analysis shows that the 5 day precipitation sum from 22 to 26 January 2010 represents the most exceptional rainfall metric of this analysis, with a precipitation value of more than 130 mm. The return period of such a 5 day-event is estimated to be on the order of magnitude of 200 years based on the 47 year record. Putting the 2010 rainfall and flood events in a context of climate change, Fig. 10 indicates minimum changes in 1 day and 2 day maximum precipitation since 1965, and a moderate increase of 5 day maximum precipitation in the 1980s with a stabilization on a higher level since then.

Furthermore, investigation of the hourly precipitation sums of the observations of the Cusco airport indicates that during the five days of highest rainfall precipitation was characterized by quite intensive short rainfalls, but the daily precipitation sums were not particularly high, which is confirmed by the 1 day and 2 day precipitation sums of the Granja Kcayra in January 2010 with approximate return periods of 5 to 20 years (Fig. 9). Taking this into account, it seems that the unusual sequence of wet days is more important for flood events in the Cusco area than a single extreme precipitation event. This may be an important information when planning a flood warning system. With respect to the relation between climatic extreme events and disaster losses it is interesting to note that the days where most people affected were registered (in SINPAD) coincides with the days of maximum precipitation (21 to 26 January, Fig. 8).

5 Discussion and conclusions

The criteria for inclusion of events in the disaster databases analyzed here are rather arbitrary, and furthermore often not handled in a consistent way. Recent assessments in fact acknowledge the large differences in reporting, documentation, completeness and quality of disaster databases (UNDP, 2013). However, there is yet limited understanding of the related implications when such disaster data are analyzed and conclusions drawn. Methods to circumvent or mitigate these problems have rarely been developed. This is especially true for developing countries where insurance penetration is low and therefore disaster databases of large re-insurance companies are of limited use.

In this study, we address this subject by focusing on three disaster databases for the case of Peru. The comparative analysis of the three databases is performed across multiple dimensions which was necessary to account for the different characteristics, strengths and limitations of each database. The dimensions analyzed include (1) spatial scales, from local to regional (provincial) and national scale; (2) time scales, from single events to decadal trends; and (3) disaster categories and metrics, including the number of occurrence, and damage metrics such as people killed and affected. The disaster types were handled in a consistent way, focusing on climate and weather related extreme events.

For the analysis of disasters trends in Cusco and Apurímac we combined the spatial and temporal scales to gain a more comprehensive picture. The analysis using DesInventar was only done for the category of disaster occurrence since damage metrics are not sufficiently well documented at this spatial scale over decadal time scales. Maybe surprisingly, the analysis does not reveal any striking pattern in disaster occurrence over the past four decades although it shows a clearly higher number of disasters in the last decade in one “Region” (Apurímac) and therefore also highlights region-specific trends. Overall, an analysis of underlying causes of observed patters in disaster occurrence is difficult and essentially limited by availability of required data. It is furthermore not a main focus of this study.

To adequately account for the limitations of damage metrics reported in the databases, we analyzed the national scale picture for Peru. We have seen that the number of people killed is approximately stable over the four decades, even though exposed population has greatly increased. The number of affected people, however, strongly increased during the same time period.

Similar differential trends in these two disaster loss and damage metrics have been seen in other countries such as Colombia (Marulanda et al., 2010; UNISDR, 2013) and are generally consistent with global trends (Golnaraghi et al., 2009).

The result that the number of people killed remained approximately stable (or even decreased) is remarkable given the population growth since the 1970s. The reasons for this reduction in mortality are not known in detail for Peru, but we may assume that improved efforts in disaster risk reduction by government and non-government institutions are at least one factor, just as suggested for the corresponding global-scale trends (Golnaraghi et al., 2009; WMO, 2013).

The reasons for the observed increase for the other damage and loss metric, i.e. people affected, have not yet been analyzed in detail for Peru either but there is little doubt that the strong increase in population is a main driver since it generally implies an increase of exposed people. However, at this point it is important to consider not only the absolute numbers of people affected but also the relation to total population dynamics. Table 1 indicates that in both disaster databases the mortality rate due to weather and climate related disasters is decreasing over the past four decades in Peru. On the contrary, the ratio of affected population to total population is increasing in both databases, yet according to EM-DAT almost with a factor of 10 between the 1970s and the 2000s, whereas in DesInventar with a factor of 4 for the same period.

There are two pertinent conclusions we can draw from this analysis. First, the difference of the loss and damage ratios and rates depending on the database analyzed can be enormous, and consequently, the interpretation and implications in terms of policies and actions could be different as well. Second, the protection of lives has been improved over time, but the vulnerability of people, as a driver of disaster damage (i.e. people affected) has likely increased. The second conclusion should be further explained here. Disaster loss and damage (including people affected) can be seen as a proxy for disaster risk which is a function of the frequency and magnitude of the physical weather event, exposure and vulnerability of people or assets (Huggel et al., 2013; IPCC, 2012). Observed changes in disaster damage can be a result of a change in one or more of those variables. A detailed related analysis would, however, require a more comprehensive data set that is generally difficult to obtain. The fact that the ratio of people affected to total population is rising over time implies that exposure is likely not the only driver, especially when considering the magnitude of increase. Frequency and magnitude of the extreme weather events, and vulnerability, remain as possible drivers. Although a comprehensive study is missing we have no indication that extreme weather events at the national scale of Peru over the past decades have significantly changed (see also Fig. 10), and hence, vulnerability remains a likely driver of change. However, we should stress that currently available data and information are not yet sufficient for more definite conclusions and more research is needed. Other recent studies suggest a decline in vulnerability in many world regions, including South America (Peduzzi et al., 2012), but whether the average number of people killed per million exposed, as used in their study, is an adequate proxy for vulnerability is not clear. Cutter and Finch (2008), for instance, emphasize the dynamic nature of vulnerability and have found both positive and negative trends in the US.

For the 2010 Cusco heavy rainfall and flood events we were able to shed light on the frequency and intensity of a single extreme event and related damages as reported in two databases. We have shown that the 2010 Cusco rainfall and flood disaster was exceptional, and also statistically extreme, in terms of rainfall amounts, and at the same time caused extraordinary damage in terms of people and assets affected.

The simple loss and damage analysis of the 2010 event again showed the large difference in records of different disaster databases. Generally, our comparative analysis indicates that ignoring such differences and shortcomings in disaster analyses over different spatial scales and time periods can result in important flaws in the conclusions on trends or other aspects relevant for adaptation and risk reduction. The lack of standards concerning the evaluation of disaster impact and loss (Guha-Sapir and Below, 2002) makes an analysis over larger geographic spaces a challenge. EM-DAT defines clear criteria for inclusion of events in the database and should therefore provide a higher level of consistency. However, in EM-DAT, as seen here, the great majority of small-to-medium-sized disasters goes unnoticed. This is an important shortcoming because presumably the cumulative impact of small-to-medium-scale disasters is decisive for livelihood and poverty dynamics in countries like Peru (Hardoy and Pandiella, 2009; Marulanda et al., 2010).

In view of a maximum value of disaster databases for disaster risk reduction and climate adaptation efforts we identify the following conclusions and recommendations: (i) for any analysis of disaster databases the type, method and source of documentation is crucial and should be carefully evaluated; (ii) the criteria for reporting disaster events are important but often not sufficiently clear and established in an arbitrary way; (iii) the sources of information and documentation should be strengthened, in particular with regards to damage and impact data; (iv) coordination between different databases would be desirable to avoid generation and communication of different results and conclusions.

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Table 1. A comparison of different metrics of weather and climate related disasters in Peru in the EM-DAT (upper table) and DesInventar (lower table) databases. Note that the information on total population is derived from census from individual years, i.e. 1972, 1981, 1993, 2007. Sources: CRED (2013), DesInventar (2013), and Instituto Nacional de Estadística e Informática (INEI), Perú.

	No. of events	People killed	People affected	Total population	% No. of events	% People killed	% People affected	Mortality disaster rate	Rate of affected population
EM-DAT									
1971–1980	7	1683	366 440	14 121 564	100.0	100.0	100.0	0.000119	0.026
1981–1990	23	2038	1 068 495	17 762 231	328.6	121.1	291.6	0.000115	0.060
1991–2000	19	1281	4 758 467	22 639 443	271.4	76.1	1298.6	0.000057	0.210
2001–2010	32	1810	6 034 115	28 220 764	457.1	107.5	1646.7	0.000064	0.214
DesInventar									
1971–1980	2187	1646	109 027	14 121 564	100.0	100.0	100.0	0.000117	0.008
1981–1990	2740	1661	349 688	17 762 231	125.3	100.9	320.7	0.000094	0.020
1991–2000	3711	1437	641 807	22 639 443	169.7	87.3	588.7	0.000063	0.028
2001–2010	2493	1084	796 616	28 220 764	114.0	65.9	730.7	0.000038	0.028

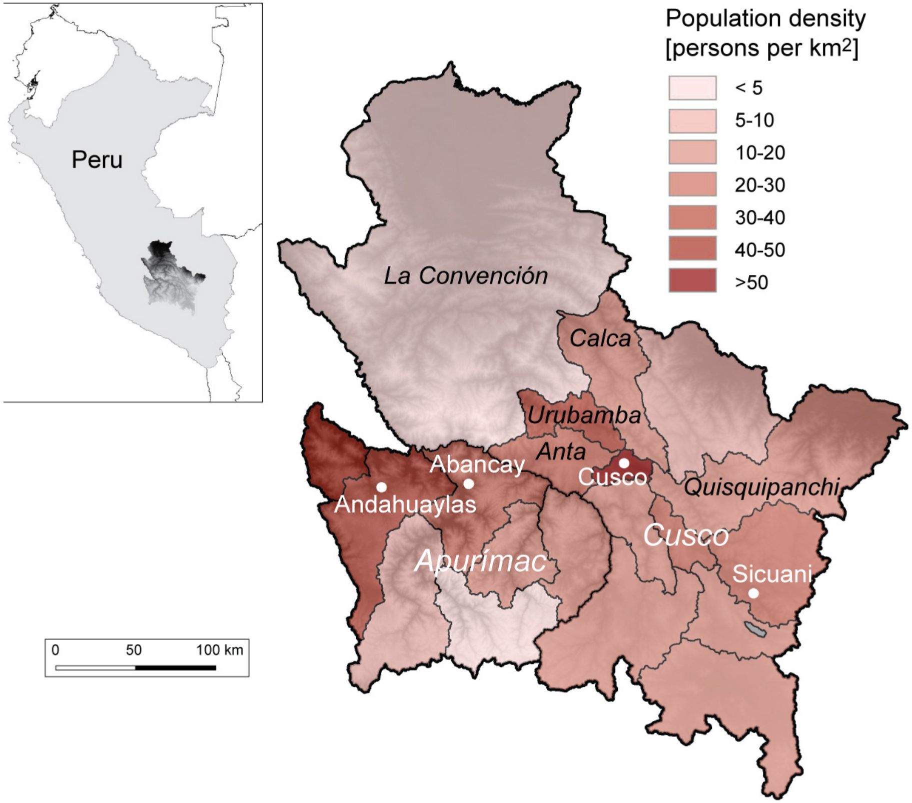

Figure 1. Map of study area with the two "Regiones" Apurímac and Cusco. Important cities are indicated in white letter, "Provincias" in the "Region" of Cusco strongly affected by the 2010 disaster in black letter. Population density is given at the level of "Provincias". Administrative boundaries of the "Regiones" appear in bold black lines while those of the "Provincias" appear in light black lines.

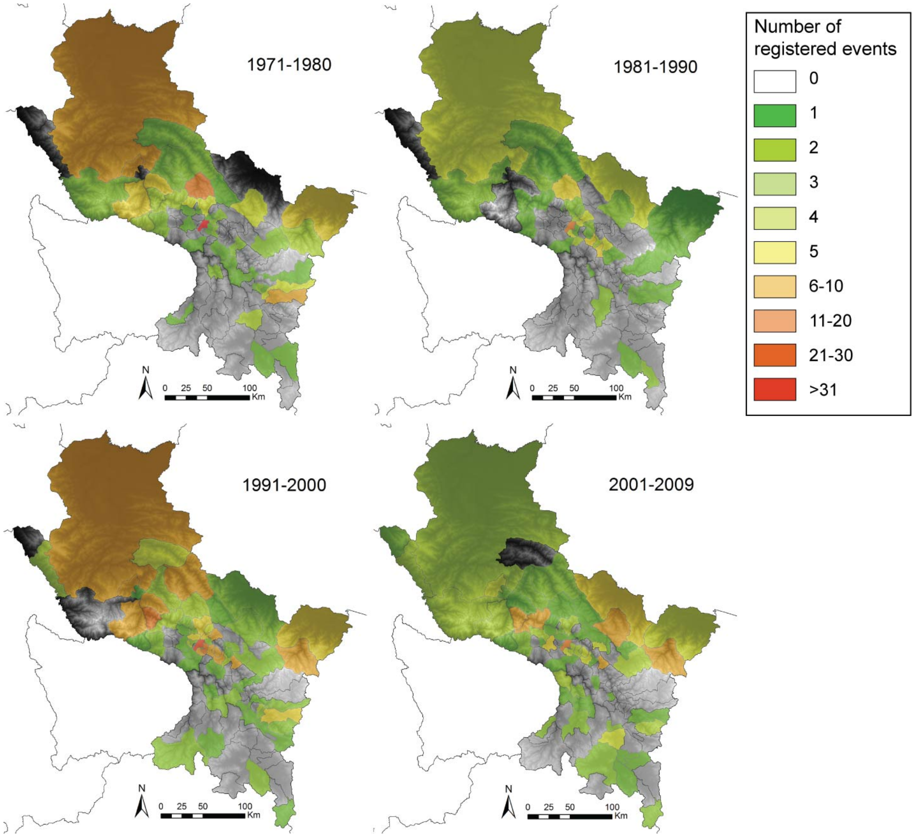

Figure 2. Spatio-temporal trends of disaster occurrence in the “Region” of Cusco at the level of “Distritos” over the four decades 1970’s to 2000’s.

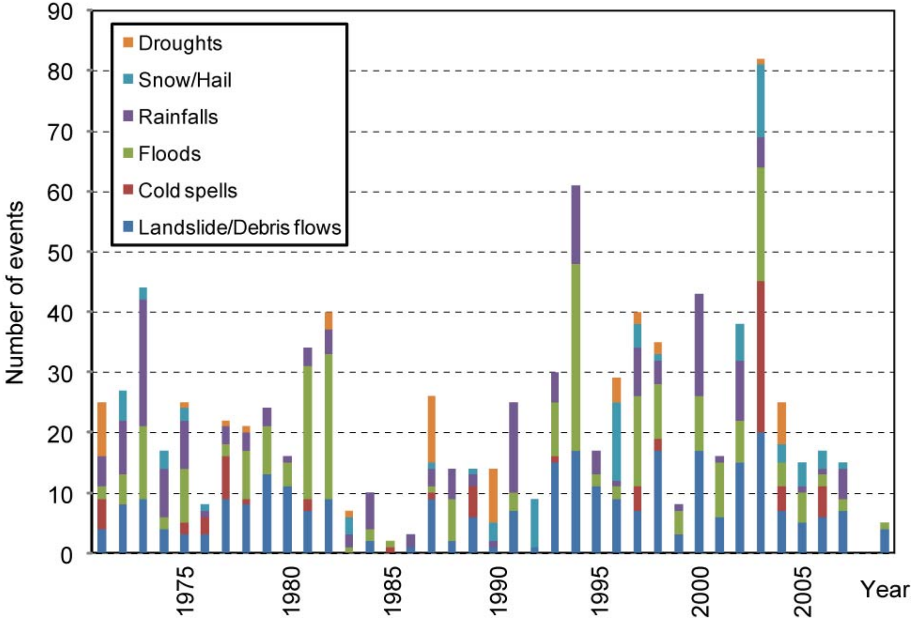

Figure 3. Number of climatic disasters in the “Region” of Cusco and distribution according to type of event (1971–2009).

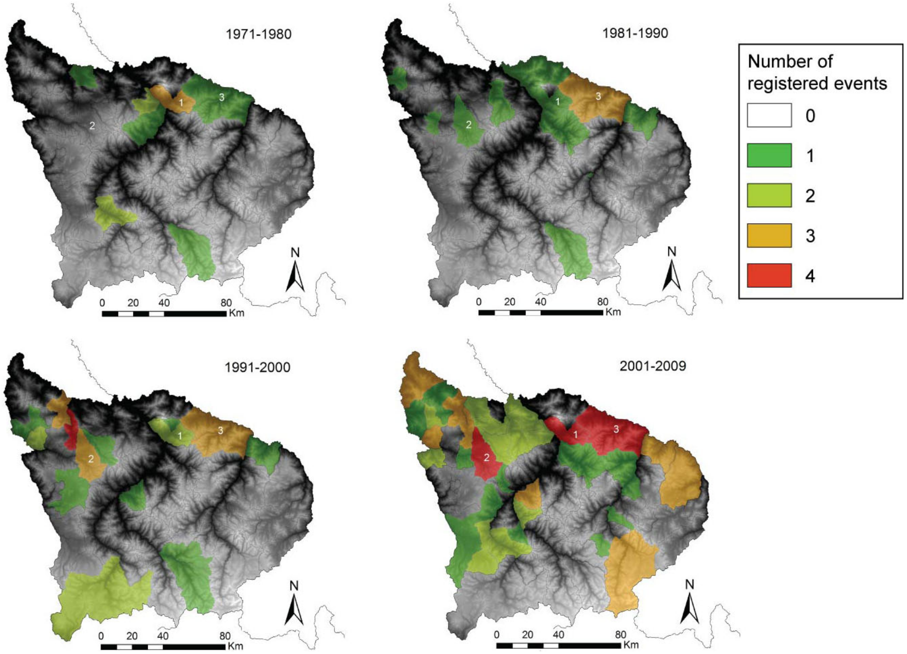

Figure 4. Spatio-temporal trends of disaster occurrence in the "Region" of Apurímac over the four decades 1970's to 2000's. Small number in white indicate most affected "Distritos": (1) Abancay, (2) Andahuaylas, (3) Carhuasi.

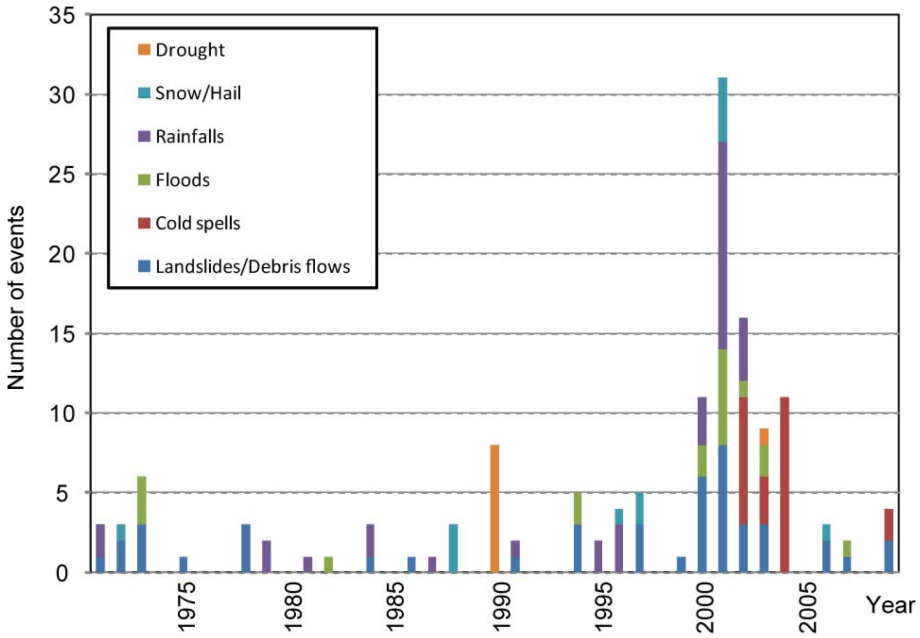

Figure 5. Number of climatic disasters in the "Region" of Apurímac and distribution according to type of event (1971–2009).

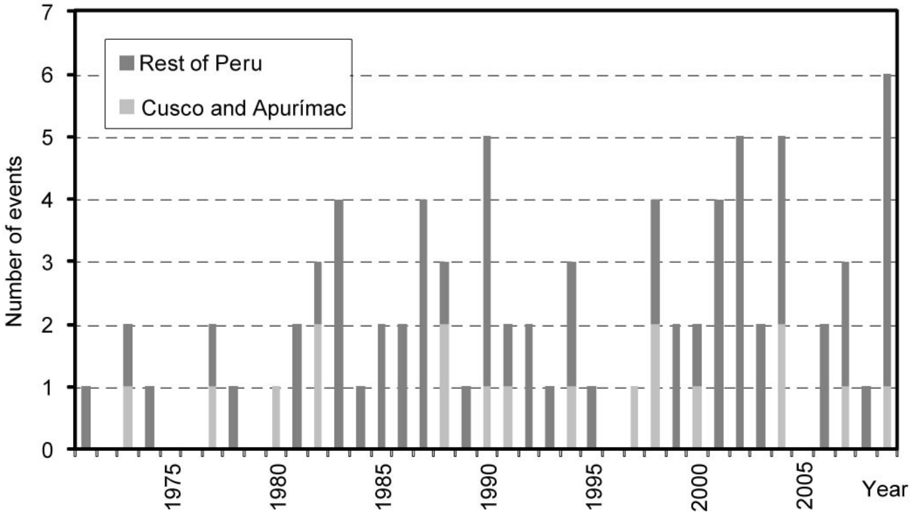

Figure 6. Number of climatic disasters in Peru over the four decades between the 1970s and 2000s, based on EM-DAT. Events reported for Cusco and Apurímac are highlighted.

Figure 7. January 2010 floods with parts of the city of Urubamba (part of “Region” of Cusco) inundated by the Vilcanota river in the Urubamba area (photo: Municipalidad de Urubamba).

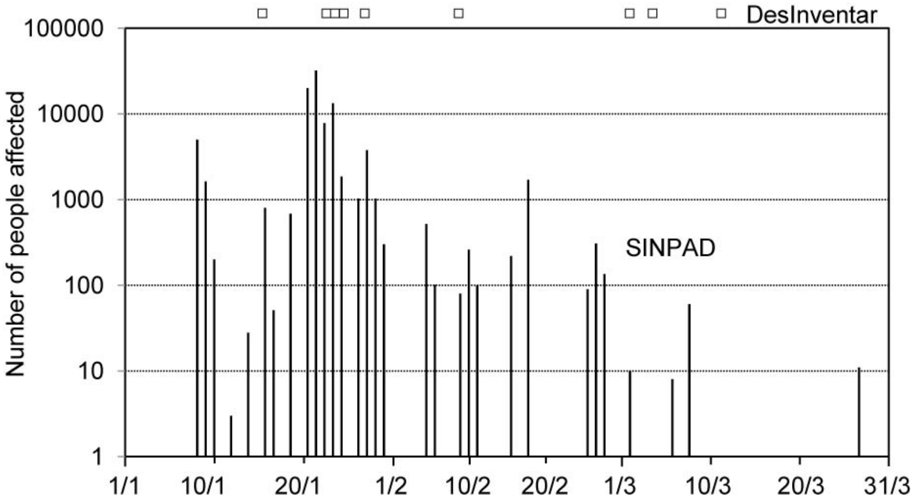

Figure 8. Comparison between individual disaster events for the January to March 2010 period as registered by DesInventar and SINPAD for the "Region" of Cusco. The number of people affected only refers to SINPAD records, DesInventar just indicates the date of occurrence.

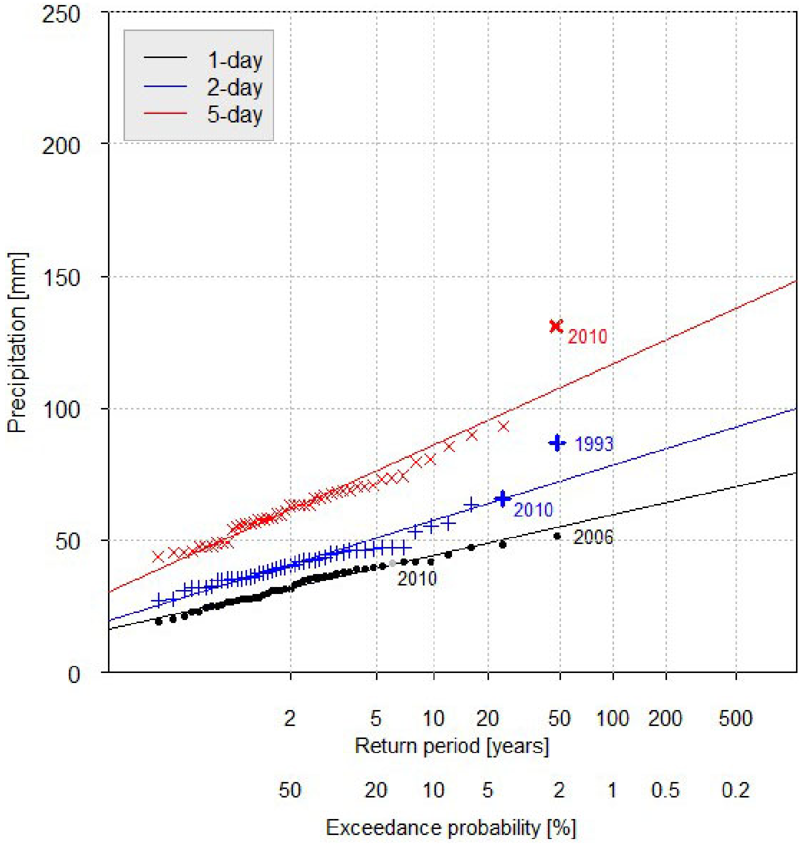

Figure 9. Extreme value distribution of 1 day (red crosses), 2 day (blue crosses) and 5 day (black dots) precipitation sums of Granja Kcayra near the city of Cusco (Data SENAMHI), arranged by their respective ranking, beginning with the lowest sum and ending with the highest Reference period is 1965–2011. The x-axis is scaled with Gumbel extreme value distribution.

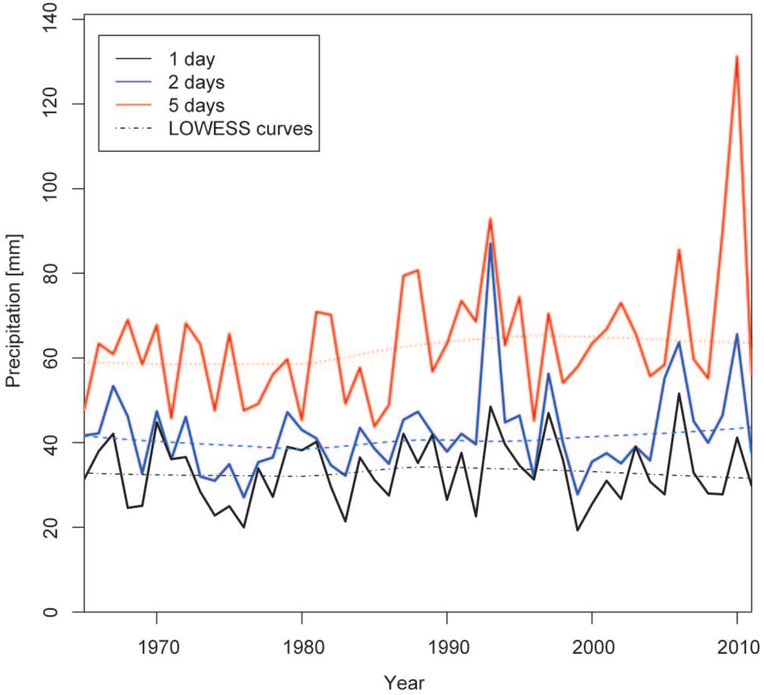

Figure 10. Analysis of 1, 2, and 5 day maximum precipitation based on data from the local meteorological station Granja Kcayra (Cusco) between 1965 and 2011. Trends are calculated using a locally weighted polynomial regression (LOWESS) and indicate minimum changes in 1 day and 2 day maximum precipitation, and a moderate increase of 5 day maximum precipitation in the 1980s with a stabilization on a higher level since then.