

EXTREME AGROMETEOROLOGICAL EVENTS^α

A discussion leading to the Terms of Reference for a DATABASE

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1. Introduction

Strictly speaking, extreme agrometeorological events include the direct and indirect impacts of extreme weather events on agriculture, taken in the broadest sense to include crops, livestock husbandry, fisheries and forestry. Extreme factors will eventually lead to extreme agrometeorological events and disasters only if they interact with a vulnerable agricultural system.

The discussion below attempts to cover, at least from a methodological point of view, the impact of other extreme events as well, including some man-made disasters like chemical accidents and the consequences of earthquakes and volcanic eruptions.

This approach is justified because of

- the existence of many border cases where non-agrometeorological events lead to situations very similar to those traditionally falling into the province of agrometeorology, or the interaction of an extreme agrometeorological event with another geophysical or other extreme factor. Examples are floods resulting from earthquakes or dam failures, or fires resulting from earthquakes or meteorite impacts. More examples are provided below;
- extreme factors often result from a chain of consequences of which only one has an atmospheric component, but the proper assessment of the phenomena requires that they be analysed as a whole;
- the need to take into account not only direct and indirect atmospheric effects on production, but also their impact on tools, infrastructure and even general marketing conditions (access to markets) and weather-dependent price fluctuations.

We also suggest that the wording *extreme agrometeorological events* is somewhat contradictory in that many extreme events become “agrometeorological” only insofar as they affect agriculture. For instance, a tropical cyclone may be an extreme geophysical factor, but it will become an extreme agrometeorological *event* only if it hits an agricultural area and quantitatively or qualitatively affects agricultural production. The unusual combination of moisture and temperature that eventually triggered the 1845/46 Irish potato famine (Bourke and Lamb, 1993) would not have been

an extreme agrometeorological event had white potatoes not been introduced to Europe, etc.

By definition, a disaster is the result of the interaction between an extreme factor and a vulnerable system (Susman et al., 1983), a definition which should also lead to adopting consistent definitions of the related concepts of risk and vulnerability (Gommes, 1998).

A database of extreme agrometeorological events should thus more properly be called a database of agricultural disasters resulting from extreme geophysical factors.

The purpose of a database of extreme agrometeorological events is, of course, to identify patterns of impacts on agriculture with a view to improving impact assessments, including impact forecasting, mitigation, adaptation and emergency operations whenever feasible. The proposed database is thus to be seen essentially as an operational tool.

The section below therefore starts with an attempt to list extreme factors which can potentially interfere with agricultural production.

2. Categories covered

It is obvious that a database of extreme agrometeorological factors must include a hierarchical typology of such factors, accompanied by a precise and quantitative definition. The hierarchical structure makes also provision for insufficiently defined extreme events referred to as a relatively broad category. Only after a proper typology will have been defined will it be possible to provide a more complete outline for the structure of a database, if particularly the description of the extreme factors and impacts has to be quantitative.

The following provides a tentative list of factors, which should be taken into account, classified according to the highest categories of a potential typology, based on the "geophysical" source of the disasters. Other approaches are possible, for instance by detrimental factor, e.g. "mudslide" regardless of the cause of the mudslide (heavy rain, snow-melt associated with volcanic eruption, dam failure...). It would also be possible to categorise the events by the type of impact (famine, production loss...), but this would pose some very serious, and possibly insurmountable difficulties because the impacts are often based on very subjective and insufficiently documented assessments, particularly as regards the extreme factor which led to the disaster.

We also stress the fact that weather factors are correlated, so that, for instance, high sunshine and high temperatures usually occur together and need not be dealt with separately.

2.1.1 Direct natural atmospheric factors

This includes the natural atmospheric phenomena with directly harm crops by their instantaneous intensity or through longer term exposure: the extremes (intensity, duration) of almost all meteorological elements (rain: drought, direct impact of torrential rain or hail), strong wind in tornadoes, storms,

tropical cyclones (breaking of organs, followed by high disease incidence), temperature (frost, heat-waves, high night-time temperatures). There does not appear to be obvious direct effects of high moisture. Lightning can be mentioned as the cause of human and cattle death.

The incidence of hail is usually limited, although some extreme cases were recorded, like the 1888 event in Uttar-Pradesh, which caused about 250 deaths. The "1888 blizzard" caused about 400 deaths in the NE USA. The storm of 12-15 March 1993 on the USA and Canadian Eastern seaboard killed 300 but affected 3,000,000 people, causing damage for 1.8 G\$. The storm, with records of temperatures, wind, rain, snow, was nicknamed "the storm of the century" and is generally assumed to have been worse than the "1888 blizzard".

2.1.2 Indirect natural atmospheric factors and complex interactions

The meteorological elements to be listed are almost the same as the ones given above, although the mechanisms of their detrimental action are different: rain (water logging of soils, floods, landslides, erosion), wind (abrasion by sand particles, soil erosion); temperature (increased water demand and resulting water stress, effect on sex differentiation of certain plants¹); moisture (incidence on diseases, conditions conducive to fires). Lightning is one of the causes of crop and forest fires.

Tropical cyclones constitute a perfect example of a complex interaction of factors, including strong winds, heavy rains, ocean spray, etc. Ocean spray is the salt water blown land inward and which may salinise agricultural land. Storm surges are even more harmful in terms of their impact on crop production. For a general account of salt effects in soils and irrigation water, refer to Ayers and Westcot, 1976.

Unfortunately, insufficient information is usually available both on the cyclone proper (its destructive power) and the impacted agricultural system. For instance, cyclone Hugo (1989, 17-23 September) is well documented for the deaths and damage caused in the north-eastern Caribbean and the south-eastern USA (the insured loss was 4.9 G\$). If much property was damaged, it is not always known that most of the banana crop was destroyed in Dominica, leading to long-term suffering, albeit locally.

Valuable methodological conclusions emerge from a comparison of the July and August 1993 floods in the Mississippi, Missouri and Kansas river valleys (USA), the 1981 Sichuan floods and the January and February 1995 floods in the Rhine and Meuse valleys. In the USA, although 1.7 GHa were flooded, most damage to agriculture occurred due to heavy rains in the whole basin through water logging of the standing crop. The Sichuan floods affected "only" 500 kHa, but threatened the livelihood of about 10 million people. The Rhine floods occurred outside the cropping season; they led to 250000

¹ For instance on oil palm: temperature at the time of the differentiation of the flower primordia has an effect on the frequency of female flowers, the only ones which will eventually produce oil, 3 years later. Another classical example is temperature-induced male sterility in rice.

people and most of their **cattle** having to be evacuated out of fear that the dams, many of them dating back to the middle ages, would break. In comparison, the July-August 1998 Yangtze floods affected 26 GHa of land, among others because the Chinese Government decided to break dams and to flood agricultural areas to protect downstream town.

2.1.3 Man-made factors

2.1.3.1 Atmospheric pollution as a source of soil and water pollution

Man-made pollution² is a multi-faceted issue, with many direct and indirect effects of atmospheric agents. The atmosphere plays a part in the formation of secondary pollutants (which result from the reaction of normal atmospheric gases with pollutants) as well as in the dispersion and transport of pollutants and their transfer between compartments (industrial plants → atmosphere; industrial plants → water bodies; atmosphere → soil; atmosphere → water bodies, etc.). Note that agriculture also constitutes a source of pollutants, either phytochemicals, fertilisers (nitrate pollution of the water table), manure from large plants, and greenhouse gases. For an overview of atmospheric pollution effects focusing on European forests, see ECE, 1997; for an analysis of threats to developing country agriculture, refer to Marshall et al., 1997.

Atmospheric conditions usually play an important part also in that they are responsible for the “contact” between pollutants and humans, farm animals and plants³: for instance, high moisture improves the impact of such pollutants as ozone⁴ and acids, or high temperatures favour the accelerated decomposition of organic liquids (manure), a process that consumes oxygen and which may result in severe anoxic conditions in waters or water logged soils.

Stomatal opening, and the eco-physiological factors which control it, conditions to what extent pollutants like ozone may enter in contact with physiologically active plant tissue (Kersteins et al, 1992). According to their nature, pollutants can affect plants by altering the environment (pH of soil, leaching of nutrients and mineral nutrition in general) or by physiological and biochemical mechanism.

2.1.3.2 Oils spills and well fires

Oil spills have received a lot of attention by the media (either from platform or land wells, including the recent Gulf war), and many of them have remained in the memory of people, such as the Torrey Canyon (1967), Sea Star (1972), Amoco Cadix (1978), Ixtoc-I (1979), Exxon-Valdez (1989; see Davis, 1996)...

² Not all “pollution” is man-made. An example is provided by rivers flowing through ore-rich deposits, resulting in down-stream heavy metal pollution.

³ A classical example of the combined effect of high moisture and toxic chemicals is the 1951 smog which killed about 3000 people in London.

⁴ Tropospheric ozone is probably one of the most agriculturally harmful pollutants in terms of production loss (ECE, 1997).

Their effects tend to be localised and more detrimental to the environment than to fisheries.

A special mention can be made of the 1991 Gulf War oil spill and smoke from burning wells. This caused massive air pollution and contamination of agricultural land and water supplies in the Tigris and Euphrates valleys. Black-rain damaged crops in Iran, Pakistan, Bulgaria and Afghanistan.

2.1.3.3 Nuclear accidents

Although nuclear accidents are difficult to hide due to the ease of detection of radionuclides, they tend to be reported by governments only under the pressure of the media, resulting in not too comprehensive data sets.

After the 1979 (28 March) nuclear meltdown at Three Mile Island (Pennsylvania), the 1986 (26 April) nuclear reactor accident at Chernobyl (Ukraine) eventually affected most of the immediate surroundings, Scandinavia and Western Europe (except Spain and Portugal) in varying degrees. This constitutes a perfect example of transport of pollutants over long distances (Wirth et al., 1987), their removal from the atmosphere and absorption by vegetation and the whole food chain (Marples, 1996).

2.1.3.4 Industrial mishaps

A severe case of aquatic chemical pollution of the Rhine river by mercury-based pesticides, fungicides and other chemicals, which originated in Basel (Switzerland) on 1 November 1986, mainly affected Germany and France. For almost two days, none of the governments along the Rhine knew the true nature of the chemicals flowing down Europe's largest waterway. It was estimated at the time that 350 Km of upper Rhine were "practically dead" and that it would take 10-30 years to restore it to life. Similar estimates would be useful in a database of agrometeorological disasters, if only to improve the long-term impact assessment methodologies.

2.1.4 Other geophysical factors

2.1.4.1 Volcanic eruptions

The agricultural consequences of volcanic eruptions can be categorised as "global" and "local", of which the magnitude of the former by far exceeds those of the latter. Both largely depend on the main types of ejecta, which are used to classify volcanoes from *Hawaiian* (quiet eruptions with fluid lava) to *Pelean*⁵ (very violent eruptions accompanied by *nuées ardentes* and avalanches of self-explosive lava); Stiegeler, 1976.

The *nuées ardentes* (literally *burning clouds*), i.e. high pressure and temperature gases moving at a speed of up to 100 Km/h and transporting numerous debris pose very serious threats. The most violent type of eruption

⁵ Named after the Montagne pelée, Martinique, which erupted on 8 May and 30 August 1902.

(named *Pelean*, after the Montagne pelée, Martinique, 8 May and 30 August 1902) leaves very little room for escaping and virtually burns all living beings.

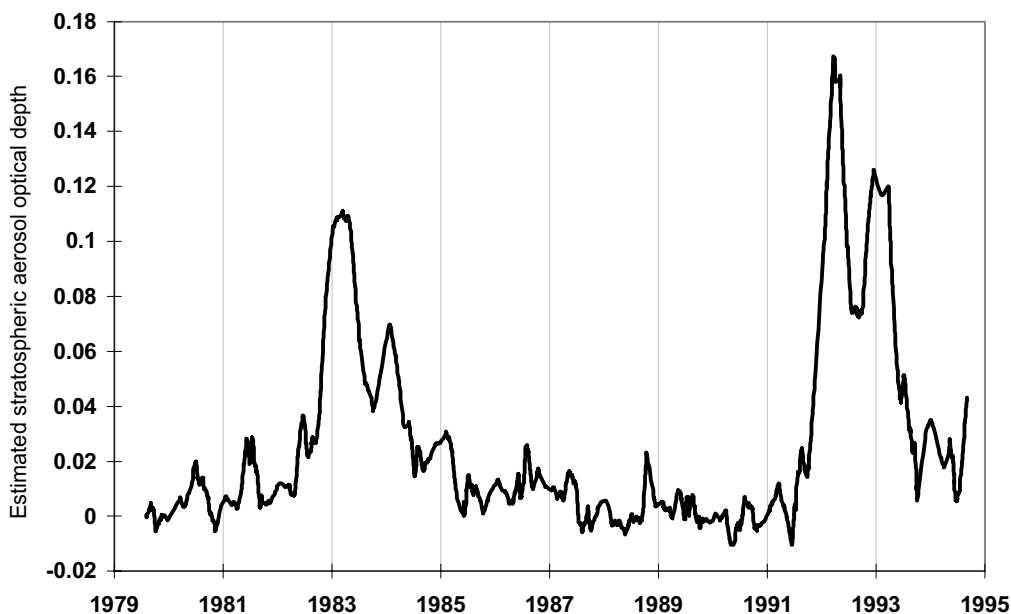
During 1783, over 12 km³ of lava and 500 Mtonnes of noxious gases were erupted during Laki Fissure eruption in Leeland (Mc Guire, 1997).

2.1.4.1.1 Global effects

Major volcanic eruptions blow large amounts of dust and gases into the lower stratosphere (15-25 km) where winds may distribute them over the globe in a matter of weeks or months. It is particularly sulphuric acid (derived from a combination of sulphur dioxide and water) that plays a significant role in lowering the earth's albedo and usually resulting in lower surface temperatures. The effect may last for several years, as illustrated in figure 1, which shows stratospheric aerosol concentrations between 1979 and 1995. The following events can be observed : 1981, Mount St. Helens eruption (USA); 1981, Alaid eruption (Aleutians); 1982, Nyamuragira (Zaire), followed, the same year, and until 1984 by El Chicon (Mexico); 1986 and 1987: Nevado del Ruiz (Colombia); forest fires at the end of 1988; eruption of Pinatubo in 1991 (Philippines) and fires in 1994. In the case of Pinatubo (June 1991), a well studied event because of its magnitude (McCormick et al., 1995, Hansen et al., 1996), the global decrease was about 0.5°C.

One of the best known historical examples is the "year without a summer" (1816; Northern Hemisphere) that followed the eruption of Tambora (Java) in 1815 (Stommel and Stommel, 1979). The eruption was widely used as a small-scale analogon of nuclear winter (Sagan and Turco, 1990). Additional details can be found in Schönwiese (1988), Briffa et al., 1998 and de Silva et al., 1998.

Figure 1: Distribution of stratospheric aerosol in association with volcanic eruptions. Based on the attenuation of the 785 nm radiation at Rattlesnake (46.4N,119.6W); data from Larson et al., 1996.



2.1.4.1.2 Local effects

Local effects can be devastating: although the characteristics of volcanic eruptions are not always so extreme, we can mention that no terrestrial species survived the eruption of Krakatoa on 26 and 27 August 1883. The eruption caused more than 35000 human victims due to the resulting tsunami rather than the volcanic eruption (McGuire, 1997).

Effects tend to be relatively local if the ashes are not injected into the upper atmosphere. For instance, the 1989 (18 May) Mount Saint Helens eruption in Washington State reached Idaho and Montana where large quantities of volcanic ash littered the soil to a depth of sometimes reaching 1 m.

As shown by the eruption of Etna (Chester et al., 1985) lava flows have the potential to cause structural damage and will destroy any buildings on their path. But most important is the fact that prime agricultural land is rapidly “inundated” and becomes useless for agriculture and other related activities for hundreds of years.

A special mention is made of the 1986 (21-24 August) “eruption” of lake Nyos (NW Cameroon) characterised by major CO₂ and H₂S emissions (Youxue Zhang, 1996). The toxic mixture caused about 3000 deaths and in Nyos village only 2 of a population of 700 survived. Poultry and cattle underwent heavy losses.

Table 1 : Losses (MUS\$) due the July 1990 earthquake and the eruption of Mt Pinatubo in the Philippines. Data from Rantucci, 1994

July 1990 Earthquake		Pinatubo eruption	
		June 1991	
MUS\$	%	MUS\$	%

Crops	22.0	38.6	44.7	10.5
Fisheries	16.3	28.6	2.3	0.5
Livestock/poultry	1.6	2.8	4.8	1.1
Irrigation	4.0	7.0	10.6	2.5
Forestry			177.9	41.9
Others, incl. infrastructure	13.1	23.0	4.6	1.2
Foregone revenue			179.6	42.3
Agriculture total	57.0	8.9	424.5	59.7
Infrastructure	273.8	43.0	66.5	9.3
Private property	158.2	24.8	205.1	28.8
Industry/commerce	104.0	16.3	15.3	2.2
Mining	21.1	3.3		0.0
Tourism	22.9	3.6		0.0
Total	637.0	100.0	711.4	100.0

The already mentioned Pinatubo eruption on Luzon (1991) covered villages and agricultural land with sterile ashes, to the extent that about 150000 people were made homeless and 600,000 lost their means of livelihood. The ash blanket reached a depth of several meters in the valleys, to an average depth of 5 cm at a radial distance of 40 km. An estimated 5000 Km² was affected. Some of the most fertile land in the Philippines had to be abandoned, leading to immediate damage and loss of future income. Mudflows created havoc in flat areas up to 50 Km from the crater, for instance by clogging fishponds. An estimated 326 KHa of forest, 43 KHa of cropland and 16 KHa of ponds were damaged. Even in 1992, mudflows still occurred and buried crops (Rantucci, 1994).

On the positive side, it must be mentioned that where the ash does not exceed 10 cm, it can be ploughed in and will increase productivity due to adequate pH, P, K, CA and Mg, even if Fe and S are excessive according to Rantucci. Similarly, Besoain et al. (1992) find beneficial effects on soils of the deposits by the Lonquimay volcano in Chile between 1988 and 1990.

Rantucci provides a detailed breakdown of the total loss incurred in the economy due to the eruption (Table 1). Agriculture accounts to 59.7% of the total economic loss, most of it in the forestry sector and in the form of foregone revenue.

2.1.4.2 Earthquakes and tsunamis

Apart from disrupting the infrastructure and destroying houses, earthquakes have little direct effects on crops. However, they often lead to secondary

extreme events causing disasters with a major agricultural component, such as fires, floods, landslides (*quod vide*) and tsunamis⁶.

The 1995 (17 January) earthquake at Kobe triggered widespread fires which contributed significantly to the estimated \$100 billion damage. About 10^7 m³ of debris were produced, which had to be disposed of. Still in Japan, the 1933 (2 March) earthquake at Miyagi, about the same number of people (3000) were killed by the tsunami that resulted from the earthquake than from the earthquake itself.

Regarding direct losses, an interesting set of data is provided by Rantucci (1994) regarding the earthquake that took place on Luzon on 16 July 1990 (magnitude 7.7 on the Richter scale). Unusually large slip motions (up to 6.2 m amplitude) were recorded, but most damage was due the liquefaction⁷ and landslides. The earthquake is seen as part of the increased geological activity in the area which also includes the Pinatubo eruption.

Table 1 is interesting in that it compares the impact of the earthquake with the eruption of Mt Pinatubo in the same area at virtually the same time of the year. As such, the agricultural setting is very comparable for the two events.

Only 8.9 % of the total damage occurred in the agricultural sector, distributed as follows: crops, 38.6 %; fisheries, 28.6 % and irrigation, 7%.

Rantucci also provides data on other disasters which have affected the Philippines⁸. During the period from 1987 to 1991, the damage due to cyclones amounted to 1.5 GUS\$, the same order of magnitude as the earthquake and the Pinatubo eruption.

2.1.4.3 Snowstorms and avalanches

Snowstorms and avalanches normally occur outside the cropping season. As such they do not normally affect crops, except winter crops, but human beings, cattle, pasture, etc. are at risk.

The February and March 1995 snowstorm in Nagqu prefecture (northern Tibet) affected 130,000 people, although financial damage was relatively limited due to the low development level of the region. Grasslands have been hit badly by what was estimated to be the worst snowstorm in 50 years, leaving hundreds of people and just under 3 M heads of livestock stranded and in danger of freezing to death.

One of the worst recorded avalanches occurred in 1970 in Peru, where 18000 people died.

⁶ Not all tsunamis are caused by earthquakes on land. The tsunami which badly hit 120 Km² of coastal areas in West Sepik (Papua New-Guinea) on 17 July 1998 was due to an earthquake that occurred in the sea.

⁷ Some earthquakes cause fine-grained materials like sand to behave like liquids, i.e. buildings and other objects sink into the ground.

⁸ The cost to the Philippines (returning residents, increased oil price) of the 1990-91 Gulf crises amounts to 0.38 GUS\$. The GNP of the Philippines was 28.6 GUS\$ in 1990.

2.1.4.4 Landslides and mudslides

Landslides and mudslides are usually associated with heavy rains, but also with earthquakes, dam failures and volcanic eruptions. In the latter case, it is often rainfall on recently fallen volcanic ashes that constitute the main source of the disaster, often entombing whole villages and sweeping away crops and agricultural land.

Two Central American examples of land- and mudslides associated with earthquakes are the following: in 1986 (10 October) in San Salvador, an earthquake and landslide made 300000 homeless; in 1987 (5 and 6 March) an earthquake in north-east Ecuador was followed by mudslides which buried several villages.

One of the most well known examples of mudslides associated with a volcanic eruption occurred in 1985 (13 November) in Armero, Colombia, after the eruption of the Nevado del Ruiz. 25,000 people died. The village of Armero was totally engulfed by a torrent of mud when La Lagunilla river burst its banks. 11,000 Ha of agricultural land was ruined. Snow-melt due to the lava flow was one of the main causes of the disaster (Nardin, 1989).

Landslides typically occur after long spells of heavy rain in areas of hilly terrain and marked seasonal rainfall patterns (dry/wet), as in Uttar Pradesh (India) during August 1998: 200 people perished; "terraces cultivated" crops and the terraces themselves underwent serious damage.

2.1.4.5 Dam failures

Data bases of disasters include a number of examples of dam failures, and it is surprising that the subject does not receive more attention. In many cases, the dams are not made from concrete and just create storage reservoirs holding less than 5 Gm³ of water used for irrigation and drinking water. Their failure leads to loss of land and often to loss of habitat, and sharply reduces the irrigation potential.

Some of the major dam failures occurred in China, for instance in 1975 (August) at Banqiao and Shimantan, Huai river, Henan province. The number of deaths amounted to 230,000. The two dams were built in the 1950s. 85000 people died within two hours of the nearly simultaneous bursts. An additional 145000 succumbed in ensuing epidemics and famines.

In 1993 (27 August) a dam failure in Qinghai province, W China, north of Tibet. Although it held only 2.6 Gm³ of water, the breaching of the dam at the Gouhou reservoir caused "big losses in lives and property" to nomadic herders and farmers in the semi-arid high-elevation plateau region.

2.1.5 Other non-geophysical factors

Epidemics are mentioned because they are frequently triggered by unfavourable conditions at least partially due to weather, because the transmission of diseases - especially vector-borne diseases - is weather

dependent, and finally because they are associated with other disasters, like floods. An example was provided above under the 1993 Gouhou dam failure.

Torrential storms in the early 1300s in Asia are often quoted as one of the remote causes of the plague which erupted in China and eventually reached Europe in the 1340s through trade routes, leading to the disastrous black plague which killed one third of the European population (McNeill, 1989).

Epidemic human diseases are mentioned because they interfere with almost all farming activities, frequently leading to secondary famine. For a general overview of human health and climate, refer to McMichael et al., 1996.

2.1.6 Very rare factors

Although they may affect agriculture, often with an indirect weather component, the following are probably not relevant in quantitative terms in the current context: transportation accidents (aeroplane crashes, railroad accidents), mining accidents and building collapse in urban areas.

Several cases of industrial explosions are known to have severely affected populations and farming.

For instance, the 1984 (2 December) methyl isocyanate gas leak from pesticide a plant in Bhopal (India) killed 3000, injured 100,000 and affected about 250,000 people. Agricultural impacts were limited (7000 cattle killed) but damage to the natural environment remains largely unassessed (Shrivastava, 1996).

The well documented dioxin release at Seveso (Italy) on 1976 (10 July) affected 36,000 people but killed large numbers of domestic fowl and pigs population. The most affected area has been sealed off since then (posing some novel institutional and legal problems). It is estimated that dioxin will have been biodegraded by 2040 (De Marchi, 1996).

A very rare event occurred in June 1908 at Tunguska where a meteorite impact took place in a deserted area of Siberia. Explosion of a stony asteroid, probably 10 km across took place 10 km above the ground (equivalent to roughly 15 MT of explosive, or 1000 Hiroshima bombs), levelling 2000 km² of forest; its radiance caused widespread fires.

3. Information to be stored in the database

The following is a proposal for a structure of a database of extreme agrometeorological events. As indicated in the introduction, we adopt a somewhat broader approach of a database of agricultural disasters of geophysical origin, including man-made disasters with an atmospheric or hydrological component.

The basic idea behind this section is that a database of extreme agrometeorological events should be comprised of 3 separate, but cross-linked, sections for each "event":

1. the precise description of the geophysical factors that caused the event;

2. the precise description of the impacted system before the event and
3. the precise description of the impact (losses), in quantitative terms.

All variables will be georeferenced.

3.1 Definition of an event

The “event” is the elementary database unit (record). A disaster can be regarded as an event, or as a succession of events. For instance, the 16 July 1990 Luzon earthquake can be treated as a whole, or each of the successive shocks, which lasted for months, can be treated as an *event*.

The event thus defines the time scale of the database unit. In addition, the spatial scale must be provided: a disaster can be analysed for the sake of convenience by administrative units or by physiographic or other logical units, including agro-economic or agro-ecological zones.

The event must be “impact oriented” to avoid difficulties when the source and the target of complex events are different. For instance, the “Chernobyl accident” occurred at precise geographic co-ordinates (130 Km north of Kiev), but the impact, which constitutes the *raison d’être* of the database occurred all over Europe. Therefore, the event would be best defined a “Chernobyl impact in Ukraine”, “Chernobyl impact in Germany”, etc.

It might also be decided to treat impacts and extreme factors separately, particularly if impacts of the same extreme factors have been felt at different times and in different areas. This will, however, require a very comprehensive spatio-temporal description of the extreme event which is not always possible nor relevant.

3.1.1 Name/code of event

This is the conventional name of the event, for instance “1845-46 Irish potato famine”, or “Chernobyl nuclear accident”.

3.1.2 Type of event

The typology of extreme events was discussed above. It constitutes an essential synthetic description of the event. One of the descriptors used in the typology must refer to the complexity and the time and spatial scales.

3.1.3 Location of event

This can be a point or a polygon of co-ordinates.

3.1.4 Timing of event

Timing and duration of event include long-term effects sometimes extending over decades.

3.1.5 Links to other events

This item provides the opportunity of vertical and horizontal links. Vertical links can point to a major causal event (e.g. “1997-97 El Niño”), while horizontal links would include pointers to events due to the same cause, for instance tropical cyclone Gilbert (9-19 September 1988) affected central America, Jamaica, Grand Cayman, Yucatan, Mexico, Texas... which may all have been treated as separate events. Or the tropical cyclone which affected Bangladesh on 24 and 25 May 1985 may have been dealt with as a separate event from the accompanying tsunami, which would make a lot of sense since the affected areas were both different and rather well circumscribed.

3.2 *The three database components - Thematic description of impacted system*

3.2.1 First component: description of the production system

The wording “thematic” refers to the agricultural or environmental description of the impacted system, of which the spatial extent was covered under 3.1.3. This item constitutes one of the weak links in current impact assessments.

In a previous CAgM report, we have underlined the factors which must be taken into account (Gommes, 1997), in particular the types of crops (varietal information if possible) and the phenological stages.

It is essential that long-term effects, including recovery, be adequately covered.

The role of agricultural research stations in extreme-factor prone areas cannot be over-emphasised as they constitute one of the most valuable sources of data for quantitative impact data, risk assessments and impact forecasting. Contrary to a common practice, observations **must** be continued after the event hits the station, among others because 100% loss is very rare. Many crops somehow recover under new agronomic and phytosanitary conditions, a situation which is difficult to model in the absence of data.

3.2.2 Second component: description of extreme factor

As with the description of the production system (3.2.1), it will be difficult to provide specific items under this heading until such time when an agreed typology will be available. We also stress that dynamic aspects of the extreme factors must be properly covered, including an estimate of return periods.

In the absence of actual measures of the intensity of most violent extreme factors such as tropical cyclones or earthquakes, impact-oriented intensity indices constitute invaluable tools, as they can combine several aspects of the destructive power of the factor or complex of factors. Palmer’s drought index, or the Saphir-Simpson scale used for hurricanes are more useful in quantitative impact and risk assessments than the pure geophysical measurements. It is often overlooked that many common “scales” (Mercalli and Richter scales for earthquakes, or the Beaufort wind scale) are empirical impact oriented scales.

The less violent extreme factors (drought, cold spells) can usually be expressed in terms of normal routine meteorological observations, although the above-mentioned synthetic indices are often very relevant as well.

3.2.3 Third component: impact assessment

Impact assessments currently constitute one of the weakest points on the path leading to a more quantitative and systematic approach. There does not appear to be a standard methodology and, even when assessments have been carried out objectively, the description of the impacted system and of the extreme factor are often insufficient. We stress again, the role of agricultural research station in the acquisition of relevant data.

3.2.3.1 Production loss

This includes both the immediate loss and the long-term losses of agricultural production.

Damage indices would be extremely useful, for instance the Typhoon Damage Index for crops (DI_c) quoted by Jose (1994),

$$DI_c = 0.37 V^{1.11}$$

where V is the sustained windspeed in Km h^{-1} . Similar indices are available for a number of applications, including ozone effect on wheat (Finnan et al., 1997).

3.2.3.2 Environmental losses

We include soil erosion, loss of biodiversity, etc. under this item.

3.2.3.3 Socio-economic impact

Essentially the financial loss by agricultural sectors.

3.2.3.4 Other aspects

Possibly an important issue, to include an analysis of how the disaster was managed, how the management increased or reduced losses, the quality of assessments that were done at the time, how the government managed the crisis: (suppression, confidentiality, recognition, amplification)...

3.3 Sources of data

Sources of data are crucial in this context, among others because comprehensive impact assessments are rarely available. Much contradicting information becomes available in the media while the extreme event is happening but final figures rarely become available. Impact assessments prepared by governments are often biased because they are conducted immediately after the events in order to obtain assistance. Among others, they rarely include long-term effects. It is also typical that different sources

quote vastly different estimates of casualties, particularly for the events that have affected very large areas and more than one country (a good example is the tropical cyclone that affected West Bengal and Bangladesh on 12 and 13 October 1970, where the total number of casualties is virtually impossible to determine).

Part of the problem derives from the lack of commonly agreed terminology and typologies. Take “people affected”, an indicator occurring in most existing disaster databases and, in one form or another, in most descriptions and analyses of disasters. The same applies to “hectarage affected” or “agricultural production loss”: not only do different authors adopt different definitions, but the area, to which the data refer, usually corresponds to administrative units where an official emergency has been declared, ignoring adjacent districts.

Finally, extreme care must be exercised for many man-made disasters, where non-technical motivations often dominate and for which a critical assessment of the reliability and neutrality of the sources is essential.

4. Conclusions and recommendations

As indicated in the introduction, it is suggested that a database of extreme agrometeorological events does not make much sense, as the event becomes “agrometeorological” only when it affects agriculture, i.e. when we have a disaster. The database should thus be one of agricultural disasters resulting extreme geophysical and man-made factors with an atmospheric component.

Almost all extreme events are likely to affect agriculture, although geophysical factors, by the large geographic extent of some of them, have the potential to lead to the largest damage in terms of instantaneous and medium-term production loss.

Regarding methodology, the following points were underlined:

- the need to develop a proper typology of impacts as the first step in the definition of data requirements and the improvement of impact and risk assessments and forecasting;
- the need to develop two types of indices, **by typology**, as synthetic tools used in impact and risk assessments. One describing the “global” intensity of extreme factors in the ambit of a specific category of disaster, and the other relating elementary extreme events (e.g. maximum instantaneous wind speed) with observed agricultural damage;
- the need for agricultural research stations to continue and intensify their observations after the occurrence of extreme events, in order to provide badly needed quantitative impact and factor data sets.

Regarding the structure of the database, there should be three separate, but cross-linked, building blocks:

1. the precise description of the geophysical factors that caused the event;
2. the precise description of the impacted system before the event and
3. the precise description of the impact (losses), in quantitative terms.

All variables will be georeferenced.

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