CHAPTER 3

CHARACTERIZATION OF PHYSICAL EVENTS CAUSING AGRICULTURAL DISASTERS

3.1 DEFINING THE EVENT

An event corresponds to one or a combination of physical and biological phenomena that cause an agricultural disaster. It is essential to identify components that have a significant impact on the vulnerable systems. For example, in the case of Hurricane Mitch (see Part B), wind had no major effect on local agricultural production systems, except on support system elements such as buildings, and on some trees: the major factors were torrential rain (direct impact) and flooding (indirect impact). Had the area been a major banana production area, the effect of wind would have been considered a major impact.

Disasters have been grouped using different classification criteria, such as the type of physical phenomenon, origin (natural, man-made), intensity or hazard, etc. Generally, extreme events are insufficiently defined due to the hierarchical structure of disasters. Table 3.1 provides a tentative list of factors to be taken into account in agricultural disaster assessment, classified according to the highest categories of a potential typology[14].

Further subcategories could be developed, based on magnitudes, combinations of different events, etc. Other approaches are possible, for instance, by detrimental factor regardless of the cause, or by the type of impact. However, the last-named options would pose some very serious, and possibly insurmountable, difficulties because they are often based on very subjective and insufficiently documented assessments, particularly with regard to the extreme factor that led to the disaster.

[14] See further details in Gommes (2003).

TABLE 3.1

Factors contributing to a disaster event

CATEGORY	EXTREME EVENTS
Direct atmospheric factors and their interaction	Rain/drought, hail, snow. Tornadoes, storms, cyclones. Frost, heatwaves, high nighttime temperatures (extreme climatic conditions). Thunderstorms, lightning.
Indirect atmospheric factors	Land slides, mud slides, avalanches. Flooding, salinization, coastal erosion, fire, etc. Disease and pest epidemics.
Other geophysical factors	Volcanic eruptions. Earthquakes and tsunamis. Very rare factors: meteorite impact, etc.
Human-induced factors	Wars. Atmospheric, soil and water pollution. Oil spills and well fires. Nuclear accidents, industrial mishaps (hazardous materials related events). Dam failures, bush fire, etc.

3.2 INFORMATION DATABASE ON DISASTROUS EVENTS

An International Disasters Data Base (EM-DAT) has been set up by OFDA/CRED[15]. This database contains essential data on the occurrence and effects of historical mass disasters in the world from 1900 to the present. It provides general information, such as disaster location (country), type of disaster, number of people affected, estimated damage, and information sources. This Excel-format database appears very useful for selecting events about which further information needs to be stored.

Based on this database (used as a checklist), a number of well documented disasters could be selected to contribute to the RADAR historical database. The local disaster-information DB, however, needs to include further, mostly georeferenced, elements, such as:

(i) event magnitude, duration and distribution;
(ii) related event intensity impact on agricultural production systems;
(iii) area affected (including geo-referencing);
(iv) area components (parcels) and their characteristics (descriptions);
(v) percentage loss recorded for different environment components; and
(vi) milieu component values and assessed damage.

Continuous augmentation of the RADAR DB with information and data from historical and ongoing events constitutes a prerequisite for MB and KB adjustment and fine tuning.

15 See www.em-dat.net.

3.3 REFERENCE DATABASE OF AFFECTED SYSTEMS

Defining the components of the milieu and their absolute and relative values is beyond the scope of this report. However, a first attempt could be made at enumerating the possible components[16] that could be evaluated within the context of *agricultural disasters*. A tentative typology of the main components related to agricultural production systems is shown in Table 3.2.

TABLE 3.2

Tentative set of components for the milieu related to *agricultural production* for which the value should be determined in each parcel, including sub-classes

	COMPONENTS	TYPICAL SUBCOMPONENTS IDENTIFIED (ACCORDING TO MILIEU)
Resource systems for agricultural production	Natural resources	Land and Soils, water (river, rainfall, etc.), biological resources (vegetation, seeds, animal breeds, etc.).
	Human resources	Number, age, sex, labour force, agricultural expertise, community organization etc.
	Socio-cultural resources	Knowledge, traditions, education, religious symbols, etc.
	Other resources	Product quality “label”, etc.
Activity and production systems	Crop systems	Food crops, cash crops, fruit crops, etc.
	Livestock systems	Cattle, sheep, chicken, etc.
	Forestry systems	Timber, fuelwood, non-timber products
	Fishing systems	Coastal fishing, ponds, etc.
	Hunting systems	Large or small animals.
	Gathering systems	Medicinal plants, mushrooms, honey, etc.
Support systems (including organization and infrastructure)	Farm buildings and infrastructure	Shelters, barns, sheds, nurseries, silos, stores, greenhouses, shade houses, irrigation systems, etc.
	Machinery and tools	Tractors, ploughs, pumps, boats, combine harvesters, hoes, hand tools, etc.
	Input supply system	Fertilizer, pesticides, seed, feed, fuel, energy, irrigation channels, pipes, etc.
	Access and marketing system	Roads, canals, aqueducts, airstrips, ports, bridges, marketplaces, etc.
	Agricultural research and extension system	Labs, experimental plots, training facilities, etc.
	Economic and financial resources system	Money banks, cooperative infrastructure, credit supply system, etc.

16 An adapted frame of agricultural components and their relative importance within the local production system (in producers’ eyes) appears as a prerequisite to avoid (expert-)biased impact evaluation.

The grouping in the table is arbitrary[17] and reflects one possible organization of the DB for the components of the milieu of each parcel in the area of the assessment.

Resource systems include the basic components of the milieu that are essential to sustain agricultural production systems and are therefore included in the short- and long-term impact evaluation. Natural resources such as land, water and biological resources (seeds, animal breeds, etc.) constitute the basis for farming systems. Natural resources should be viewed as the source and sink terms, since they are the physical "surface" where the agricultural activities take place, but they also have an intrinsic value as production factors. Furthermore, *labour* is an important resource: its socio-cultural component is also needed because expertise, production experience and organization are often the concerns of specific community members.

Activity systems include the various types of agricultural activities and related production systems: crops, livestock, forestry, fishing, hunting and gathering. To evaluate each of these at the time of the event, one must determine their type and respective physiological stage and quality. The attribution of a value should consider the investment made up to the time of the evaluation, the projected cost and value of the final product, and eventual production loss in the following years.

Support systems consist of the components that enable the improvement of the amount and quality of agricultural products, including

(i) farm buildings and infrastructure, machinery and tools;
(ii) input supply systems, including energy and water;
(iii) access and marketing systems;
(iv) agricultural research and extension systems; and
(v) economic and financial resources systems, including all related infrastructure and facilities.

The exact evaluation of the components of the three subsystems is specific to the region where the assessment is conducted, and attributing a value to these components requires knowledge of the production process, from both the technological and socio-economic points of view.

[17] The example of Hurricane Mitch in Part B uses a grouping (activities, lifelines and buildings, etc.) that differs from that indicated here. For future normative work, it would be advisable to adopt a standard grouping to harmonize data collection, even though the importance of components may differ according to specific local situations.

Furthermore, availability of basic updated information on farming systems and values could dramatically speed up early model output and improve its accuracy. Updated information is often derived from remote sensing imagery or technical information on farming systems, as well as socio-economic data published in recent reports and studies. However, in most cases, the characterization of the milieu needs to rely on national or regional production statistics. Such time series are extrapolated (re-scaled) and cross-checked against farming system studies and other recent rural development information sources.

A rapid analysis of the local farming systems generally allows identification of the relative importance of the different components, and facilitates elimination of non-applicable elements in relation to the event.

Damage assessment information comes from various sources (Table 3.3).

TABLE 3.3

Modalities for assessing information on damage

Rapid reconnaissance	Areal observations by trained observers. Reports sent or radioed to an Emergency Operations Centre (EOC) from designated observers (extension agents, cooperative leaders, etc.). Damage assessment reports filed with the EOC. Reports from public officials (agricultural ministry, etc.).
Complete damage assessment	Visual on-the-ground inspection by trained observers and extension workers. Reports from public officials (agricultural ministry, etc.). Reports from knowledgeable local voluntary agencies, personnel and farm groups. Reports from agribusiness interests. Detailed surveys by the agricultural ministry.

3.4 MAIN EVENT CHARACTERISTICS

Frequently, the errors in assessing the impact of an event arise from the uncertainties affecting the magnitude and the resulting uncertainties of the event and its intensity (Figure 3.1). The magnitude measures the energy of an event, while the local magnitude measures the energy of the event at any given place. Neither of them should be confused with the "intensity", which is an empirical measure of the degradation of the milieu produced by the event at the location considered.

The distinction becomes even more critical for rapid impact assessments, because immediate access to disaster areas is often impossible or difficult. In this case, the assessment needs to rely heavily on remote sensing and modelling of the event, which should provide an estimate of the magnitude and local magnitudes of the event, but will not provide estimates of the intensity or of the percentage loss.

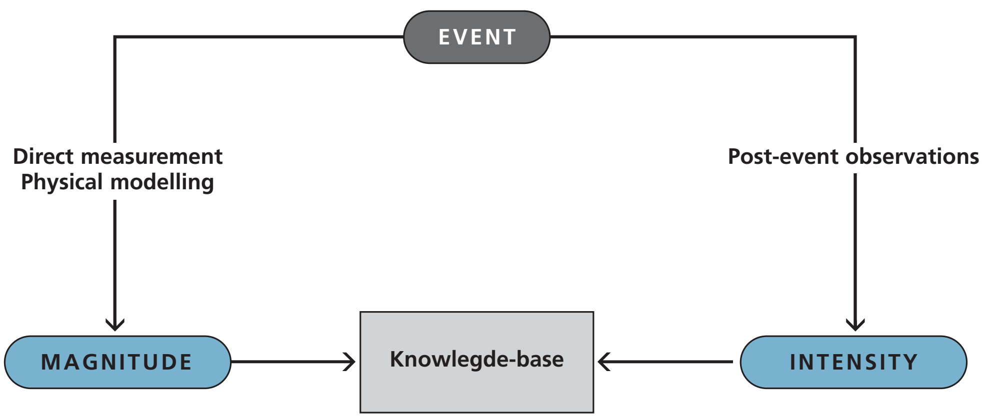
3.4.1 Magnitude

Measurement of magnitude could be performed separately or jointly by:

- direct measurements *in situ*: e.g. wind, rainfall, chemical concentration of pollutants; and
- remote evaluation: satellite imagery (rainfall, temperatures, etc.), radar imagery, etc.

FIGURE 3.1

Interrelationship among *Event*, *Magnitude* and *Intensity*



In practice, local magnitudes are often difficult to measure in the field during and after an event. Based on remote sensing and specific ground data, physical and simulation models allow determination of event magnitudes and their distribution over the affected area (local magnitudes). However, for some anthropogenic disasters, the magnitude could also be measured after the main event (chemical pollution, radiation after the passage of a radioactive cloud, etc.).

3.4.2 From magnitude to intensity

Physical modelling of an event leads to an assessment of the local magnitude of the event, but not to an estimate of the degradation of the environment, nor to an estimate of the percentage loss. However, historical data generally indicate event intensity, since it is more direct and simple to measure the degree of disruption of the environment observed after the event (especially when the event was not foreseen).

The conversion is needed of local magnitude values into percentage loss of value for the components of the milieu. From a practical point of view, this could be achieved by intensity scales for the various disastrous events. Once the scale is defined, it is relatively simple to convert local magnitude to intensity (and vice versa). Adequate KBs need to be designed to transform local magnitude to intensity in order to be able to assess the percentage loss.

From a modelling point of view, the intensity scale is a function of the locally measured magnitude on a one-to-one correspondence. At the same time, intensity may be directly measured in the field by noting the degradation of the components of the milieu: as the intensity of the event increases, different components of the milieu are being used to avoid the problems related to total "destruction" of the component.

Recording components need to be simple components[18] that can also be recognized by lay persons. One of the immediate advantages of this uniform approach is the possibility to compare and adjust the intensities computed by models to conform to those obtained through direct field observations. In addition, to determine the intensity of an event, one could prepare standard questionnaires designed specifically for different cultures to allow for the quantification of the intensity, independent[19] of the cultural context. These questionnaires could easily be compiled by local authorities (police, fire brigades,

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[18] For instance, the roofs of buildings blown away after a tropical cyclone. It is not necessary that these be agricultural components.

[19] Nevertheless, the quantification may remain sensitive to the perception of the event by different cultures.

The Red Cross, public officials, teachers, etc.) and even by non-experts in agriculture, without an immediate need to quantify the losses.

In fact, intensity scales, such as the Mercalli intensity scale[20] for earthquakes (Table 3.4), are already used for disaster evaluation. They were designed mainly for use by government offices and insurance companies.

TABLE 3.4

The modified Mercalli intensity scale for earthquakes

INTENSITY	DESCRIPTION	ENVIRONMENTAL DISRUPTION
1–4	Moderate	No damage.
5	Rather strong	Damage negligible. Small unstable objects displaced or upset; some dishes/glassware broken.
6	Strong	Damage slight. Windows, dishes/glassware broken. Furniture moved or overturned. Weak plaster and masonry cracked.
7	Very strong	Damage slight to moderate in well-built structures; considerable damage in poorly-built structures. Furniture and weak chimneys broken. Masonry damaged. Loose bricks, tiles, plaster and stone will fall.
8	Destructive	Structural damage considerable, particularly to poorly-built structures. Chimneys, monuments, towers, elevated tanks may fall. House frames moved. Trees damaged. Cracks in wet ground and steep slopes.
9	Ruinous	Structural damage severe; some structures will collapse. General damage to foundations. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground; liquefaction of soil.
10	Disastrous	Most masonry and frame structures and foundations destroyed. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dykes, embankments. Sand and mud shifting on beaches and flat land.
11	Very disastrous	Few or no masonry structures remaining standing. Bridges destroyed. Broad fissures in the ground. Underground pipelines completely out of service. Railway rails distorted. Widespread earth slumps and landslides.
12	Catastrophic	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted.

20 Other scales are the Saffir-Simpson scale for hurricanes and the Fujita scale for tornadoes, mainly designed for evaluating the damage to buildings and for saving lives.

In fact, for rapid impact assessment of disasters in agriculture, these intensity scales are not usually applicable. Specific intensity scales need to be defined for each kind of event and degradation of the components of the milieu that are targeted (agriculture, infrastructure, etc.).

Among the various disastrous events, earthquakes differ from the other categories because the source of the event is inaccessible and remote and cannot be observed or studied directly from the place where the event strikes. Other extreme events, such as tropical cyclones, may be identified, tracked and measured directly as they travel over the surface of the Earth. Historically, this difference has brought about a distinction in the way earthquakes were studied relative to other hazardous phenomena. Already by the end of the eighteenth century, scientists understood that the environment was "recording" earthquakes with different amount of disruption of the milieu (intensity) related to the distance from the epicentre (Mercalli intensity scale).

By the middle of the nineteenth century, when many more seismometers were deployed, scientists defined the magnitude of an earthquake (based on a logarithmic scale by Richter) as a measure of its energy obtained directly from the seismometer recordings. Later studies identified the correct relationship between the magnitude and the intensity of an earthquake.

Today, the energy of earthquakes is measured only with the Richter magnitude scale. However, there have been two hundred years of recorded experience in relating environmental disruption to intensity and intensity to magnitude of earthquakes, so that it is easy now to follow the opposite route. All of the recorded experience mentioned above constitutes, in fact, a knowledge base for earthquake impact assessment.

3.4.3 Defining intensity scales

There is a general lack of intensity scales for most kinds of hazards. In particular, no consistent work has been done in agriculture to identify an intensity scale for relevant disastrous events. Therefore, for a rapid impact assessment, it is essential to develop standard scales of intensity that can be used for agricultural impact evaluation, for each category of destructive event. In defining the scales of intensity, a number of preliminary general rules should be observed:

- the scales should be simple and easy to understand, including for lay persons;
- in defining the interval between subsequent grades of each scale, there should be ideally a direct correspondence with the grades of local magnitude of the event (expressed in linear or logarithmic form).

The intensity scale may have a lower limit cut-off (determined by the minimum damage), but no upper limit;

- the components of the milieu that will be used to define the intensity at the various grades need to record the event without being saturated (totally destroyed) nor insensitive (too little degradation). In fact, the same components may or may not be used for different grades;
- at each grade, there must be a sufficiently large number of alternative "recording" components to allow for redundancy and comparison of the results across locations, seasons, climate, soil composition and slope;
- in defining each scale, some kind of relationship should be established to allow transfer from event magnitude to intensity, and from intensity to percentage loss. These relations (the transfer functions) may be complex, ambiguous or ill-defined, and will form the KB. Clearly, with time and experience, these transfer functions may become better defined and more quantitative; and
- remote observations of specific events should be linked directly to event intensity.

As shown in the example of earthquakes (Section 3.4.2), long-term recorded experience in relating environmental disruption to intensity and intensity to magnitude of a disastrous event may allow the identification of the most appropriate relationship between the magnitude (energy) of the event and its intensity (degradation of the milieu at a site). Careful and systematic accumulation of data related to past experience of agricultural disasters defines the basis for building up a KB to convert magnitudes into intensities. This constitutes one of the bases of the RADAR approach.

CHAPTER 4

IMPACT ASSESSMENT PARAMETERS

The impact assessment of a disaster is a tool for evaluating the disruption of the environment produced by an event. This process and the use of generated information involve a number of institutions, with duties and responsibilities that have both local and global scope. Such institutions may have differing, possibly conflicting, objectives, even if the goals are similar and the mission is identical. Each institution needs such an assessment to minimize the disruption of the environment in a manner reflecting its own goals and objectives[21]. Thus the process of impact assessment is not a standard procedure leading to uniform results, but rather depends upon the institution. Results could be shared among institutions after careful analysis and appropriate adjustments of the assessments to reflect institutional goals and objectives.

4.1 FROM EVENT INTENSITY TO PERCENTAGE LOSS

The percentage of loss is either directly or indirectly assessed. If directly evaluated on site, the approach requires a time consuming and costly evaluation of damage. In many cases, when the disaster-affected area is not accessible, the approach is not practicable and estimations are based on approximations. Furthermore, there may be large discrepancies between evaluators. Indirect assessment derives from educated deduction from event intensity based on transfer functions generated through historical knowledge bases.

The percentage of loss or damage recorded for different milieu components is a function of event component intensity combined with the vulnerability and recovery capacity of the respective milieu components vis-à-vis the specific event. Special attention should be paid to primary and secondary effects, as well as to short- and long-term effects.

[21] For instance, the goal of a humanitarian institution may be to save peoples' lives immediately post-event; it might not be concerned with long-term recovery planning. Thus, the impact evaluation may indicate with precision the number of causalities, the number of people still at risk and the level of that risk. It may be less precise, though, in indicating damage suffered by buildings or the degree of disruption to agricultural and commercial activities.

A disaster is usually, but not always, the result of a complex event, because it generates damage through a cascade of simple and consequent events like wind, rain, flood, landslide and sedimentation. A disastrous event could also be considered to combine a primary event, which is the immediate cause of a disaster, and the consequent secondary events, which are triggered by the primary one (Table 4.1).

TABLE 4.1

Primary and secondary causes of disaster

DISASTER	PRIMARY CAUSE	CONSEQUENT CAUSES
Earthquake	Ground tremor	Eruption Flood Landslide, mudflow Sedimentation Tsunami
Erosion	Erosion	Flood Landslide, mudflow Sedimentation
Flood	Flood Sedimentation	Erosion Landslide
Hurricane	Rain Wind	Erosion Flood Landslide, mudflow Sedimentation Spray, surge
Landslide	Slide	Flood Mudflow Sedimentation
Rain	Rain	Erosion Flood
Tsunami	Tsunami	Erosion Flood, surge
Eruption	Lava flow Tephra fall Earthquake	Fire Flood Landslide, mudflow
Wind	Wind	Surge Flood

In the definition of complex events through the probability tree of direct and consequent events, the same kind of event may be identified as the consequence of different causes. Such "recurrence" problems can be prevented by some simple rules. For instance, a "flood" may induce a subsequent "erosion" event, which in turn may generate a "landslide", and the landslide, by damming the river that created flooding in the first place, may produce additional flooding. Then, the problem is the evaluation of how much additional damage is generated by the consequent flooding event. Table 4.2 presents a sum of simple events with a tree structure and may serve as a guideline for reducing the analysis of complex events.

TABLE 4.2

Simplistic structure to facilitate analysis of complex events

	CHARACTERISTICS	LEVELS
Disastrous event	Simple causing events (e.g. 5 types)	Wind, rain, surge, etc.
	Levels of intensity of the considered events (e.g. 5 levels)	Intensity classes I, II, III, IV, V
Milieu affected (and its vulnerability)	Milieu components (e.g. 5 components)	Soil loss, humus loss, etc.
	Type of soil (e.g. 10 types)	Alfisol, entisol, lithosol, mollisol, etc.
	Range of slope (e.g. 5 classes)	0–5%, 5–10%, 10–20%, etc.
	Ground cover rates (e.g. 5 classes)	0–10%, 10–25%, 25–50%, etc.
Results	Level of damage (e.g. 10 levels)	0–10%, 10–20%, 20–30%, etc.

A KB is not yet available that provides a transfer function for transforming the intensity of the event to percentage loss of value for the various components of each parcel. The development of a KB would require a sizeable amount of relevant historical data in order to be efficient. The amount of work involved in building a KB, however, will dramatically reduce the time needed for impact evaluation in the end. Also, a well constructed KB is the first step toward the implementation of a system that can become more automated and that exploits the conceptual model of a disaster to its full capacity. This KB and the relative "inference engine" must be built by experts by comparing observed and generated "field" intensity evaluations with actual percentage loss.

Based on intensity distributions and related percentage losses at parcel level according to their respective vulnerability, the distribution of percentage losses could be mapped using a GIS.

4.2 AGRICULTURAL PRODUCTION SYSTEM VALUES

The evaluation of variables such as hazard, intensity, vulnerability and percentage loss tend to be only a function of objective "scientific" observations (independent of institutions). However, the estimate of the value of the components of the milieu is intrinsically related to the goals and objectives of the specific institution performing the impact evaluation. Thus, the divergence among assessments conducted by different institutions should be limited mainly to the definition of the significant components of the milieu of parcels and to the assignment of their values. Indeed, some differences may also arise from the use of a different component hierarchy during the evaluation, prioritizing or ignoring specific components according to the institutions' objectives. Furthermore, the assignment of a value to a component of the milieu usually involves choices of an ethical, economic, political or cultural nature. Thus, the procedure to assign values may change depending on where and when an event occurs. Also, since the impact assessment is human-related, clearly this evaluation tends to be anthropocentric.

The value (relative or absolute) of farming system components may also vary according to local traditions and market prices. Because the value of the human component in the resource system cannot easily be compared to the value of the other material components, it is useful to provide two value scales. The first scale is for the labour and culture components, and is a relative scale; the second includes all the remaining components of the milieu to be evaluated on an absolute value scale, usually established in monetary units.

To determine an ***absolute scale*** of values for the component of the milieu, its commercial value before (or after) the event is generally used, even though this value may be subject to large fluctuations. In addition, the commercial value of human or cultural components may be difficult or impossible to define. In particular, humanitarian non-profit institutions cannot easily adopt this approach because of conflict with their mission and goals. In many cases therefore, one needs to define a ***relative scale*** of values. In practice, it is useful to provide both absolute and relative scales of values. In addition, whenever feasible, it is convenient to suggest an informal procedure to correlate both scales. This is because the impact may be evaluated using a number of different scales of value, the discrepancies among the various evaluations being a function of the mission of the institution performing the assessment and of the accuracy of the impact assessment itself.

4.3 OVERALL DAMAGE CAUSED BY THE DISASTER

Once the percentage loss of components at parcel level has been determined, integration of values over the affected area will provide the overall damage or toll caused by the disastrous event. A structured information management system based on a GIS platform is particularly useful in this exercise, given its capacity to automatically generate results in both tabular and map form.

In order to take into account all components of the agricultural production system and their relative importance, the structure of damage output could be directly related to the identified milieu components as in Table 3.2 (including sub-classes as required).

Infrastructure losses are in general easy to determine: the damage is equivalent to the cost of restoring items to the condition they were in prior to the disastrous event(s). Activity systems require a detailed knowledge of local production systems, because not only direct damage but also medium- and long-term production losses need to be considered, especially for pluri-annual and perennial productions, in order to assess input required to restore systems to the same level as prior to the event.

Apart from production losses, human, environmental or resource losses in general are very difficult to evaluate, especially in financial terms. In many cases, for these components, the situation as it was before the disaster cannot possibly be restored.