PART A

OBJECTIVES, CONCEPTS, DEFINITIONS AND METHODS

CHAPTER 1

INTRODUCTION

For current purposes, the definition[1] of a disaster is:

> "the general outcome of an event (sub-event) that correspondents to a significant disruption of normal life of at least the smallest human community. Disasters are the *result of the interaction between an extreme factor* – or the combination of several factors – *and a vulnerable system*"
>
> (Susman et al. 1983)

Natural disasters have killed over eight hundred thousand people in the decade between 1996 and 2005, and the economic damage of disasters now exceeds US$ 70 billion a year worldwide (International Federation of Red Cross & Red Crescent Societies, 2006). Only the most devastating damage is dealt with by the authorities or makes it into the media. Small- and medium-scale disasters are in general not registered in global databases, but may in the aggregate have caused several times as much damage. The increasing toll of disasters is linked to widespread poverty, hazard development, environmental degradation and accumulating disaster vulnerability.

Weather related natural disasters have been highlighted recently due to heightened political commitment to and public awareness of climate change. The Intergovernmental Panel on Climate Change reports that there have likely been increases in the number of heavy precipitation events in many land areas since 1950 and an increase in intense tropical cyclone activities in the North Atlantic since 1970. Observations also show that more intense and longer droughts occurred since the 1970s. The relationship between increased atmospheric concentration of carbon dioxide due to human activities and frequency and intensity of extreme weather events has not been established. However, climate model projections for the 21st century indicate that increased frequency of heavy

1 This is a definition that should also lead to adopting consistent definitions of the related concepts of risk and vulnerability (Gommes, 2003). Other more institutional definitions have also been proposed, such as "A disaster is a situation or event which overwhelms local capacity, necessitating a request to national or international level for external assistance." (Centre for Research on the Epidemiology of Disasters (CRED); see www.em-dat.net)

precipitation events is *very likely*, while increases in drought affected areas and intense tropical cyclone activities are *likely* (IPCC, 2007).

Effects of disasters on agricultural activities, especially related to traditional small-scale farming systems, are most often either neglected or considered to be of minor economic interest. There is therefore need to address the persistent obstacles of negative public perception, political expedience and institutional weakness if any headway is to be made in reducing the vulnerability of populations, infrastructure and economic activities[2]. Pro-active strategies are essential if vulnerable countries are to avoid large-scale loss of life and destruction of environment, activities and infrastructure. The international community has a vital role in assisting developing countries in setting up effective policy frameworks for reducing disaster risks.

A rapid assessment of disaster impact[3] is essential, not only for supporting the decision-making process before and during the immediate relief efforts, but also for long-term recovery planning. Rapidly evaluating the impact of a natural disaster on agriculture is a complex and multi-disciplinary procedure that is open to significant errors (see, for instance, FAO, 1997 and FAO, 2007). Even access to an area immediately after a large disastrous event may be difficult, sometimes even impossible. And there is the problem of collecting homogeneous, reliable and accurate data for the assessment, when major public and private efforts are focused on search-and-rescue operations and meeting immediate life-support needs.

Currently there is no tested, standardized procedure for carrying out such a disaster assessment in agriculture. The many problems render evaluating disaster impact a subjective, expert-biased, difficult and potentially inaccurate task, and even different missions may attribute significantly different values to the same impacted elements of the environment[4]. In many cases, the local conditions in the area of the disaster zone are such that the only possible approach for rapid disaster impact assessment in agriculture relies on qualitative and practical rule-of-thumb methods that are used by "experts" (FAO, 2007). These methods are difficult to use by non-experts, and tend to be subjective and to carry large approximations.

The technical challenges of disaster mitigation are well understood, and significant progress has been made in hazard mapping, vulnerability assessment and damage assessment. All this acquired know-how must be integrated in a Disaster

2 See also Natural Hazards and Economic Development: Policy Considerations by US Agency for International Development and Organization of American States Caribbean Disaster Mitigation Project (http://www.oas.org/cdmp/document/econpoly.htm)

3 For example, Palmieri et al. (2006) propose a rapid impact assessment of tropical storms.

4 See Table 1.4 on page 10 for definition.

Information Management System (DIMS) in which a "model-base", a "knowledge-base" and a "database" are combined with a Geographical Information System (GIS) platform. Such a tool set can be used in impact assessment procedures to quantify (assess) the impact of an event. The accuracy of the assessment should improve over time as more data and experience are incorporated into the DIMS.

TABLE 1.1

Disaster-related fields where a DIMS could be used to advantage

Relief	Programmes that facilitate the exchange of information or provide short-term assistance, or both, usually in the form of food, clothing, blankets, temporary shelter, etc., for people who have suffered injuries or incurred losses due to a major disaster.
Recovery	Programmes that provide longer-term assistance for people who have suffered injuries or incurred losses due to a major disaster, with the objective of facilitating the return of these communities to their pre-disaster condition.
Preparedness	Activities, programmes and systems developed prior to an emergency that support the development and dissemination of information and training about how individuals and organizations can prepare for a major disaster or large-scale emergency.
Mitigation	Programmes that provide services that enable individuals and organizations to make physical preparations prior to a disaster or emergency, thus reducing loss of life, personal injury and destruction of property when an incident actually occurs.
Education and Training	Programmes that provide training for the public and private sector to enhance emergency-response planning and the level of overall preparedness by government organizations, community-based agencies, individuals and families.
Research	Organizations, institutions and programmes that are devoted to research into natural disasters, their mechanisms, and responses to disaster.
Response	Organizations that are responsible for taking action before, during and after the onset of a major disaster or large-scale emergency in order to end the emergency, preserve lives and limit damage.
Warnings	Programmes that issue alerts, advisory notices and warnings to inform the public of an impending event such as a major fire, flood, hurricane or tornado that has the potential to cause loss of life, personal injury or to destroy property.

Beyond rapid damage assessment in the agricultural sector, the areas of application of the DIMS also extend to several related fields, such as preparedness and recovery planning and early warning systems. The DIMS could be used most appropriately in various fields, including those itemized in Table 1.1.

However, disaster mitigation is a difficult sell – one of the principal lessons that has emerged from the implementation of the Caribbean Disaster Mitigation Project (CDMP)[5]. Governments and the private sector traditionally fail to consider the potential effects (especially long-term impact) of natural hazards when proposing regional development plans and investing in physical or economic infrastructure. In addition, major institutional limitations persist in the implementation of risk reduction measures.

1.1 OBJECTIVES

After briefly defining a hierarchy of aims and discussing a framework for the problem, Part A of this document develops the view that simple and quantitative procedures can be designed and applied, at least concurrently with the rule-of-thumb methods, for rapidly assessing the impact of disasters (sections 1 to 4). A Rapid Agricultural Disaster Assessment Routine (RADAR)[6] is described, based on a theoretical approach that uses simple tools for assessing the impact on agriculture of a disastrous event. The report gives quantitative definitions for all variables used, and discusses the need for developing intensity scales for the different types of events, as well as value scales for the elements of the environment. The second part of the report (Part B, sections 6 to 8) illustrates the concepts presented in Part A in a detailed case study covering the impact of Hurricane Mitch in Honduras (1998).

The development of the RADAR procedure, and particularly its implementation in a decision-support system (DSS), conform to the mission of FAO in emergencies (FAO, 1997). As a normative institution, the mission of FAO is to provide tools and methodologies to member countries: this goal is reflected in RADAR through a pro-active standard methodology to be implemented in the area of the disaster during impact assessment.

The goal of RADAR is to provide FAO with the necessary information in the decision-making process for *minimizing the short- and long-term impacts of disastrous events* in agriculture.

The objective of RADAR is the development of a practical tool (decision-support model) for assessing, with adequate rapidity and accuracy, the area distribution of short- and long-term damage due to the effect of disastrous events on agricultural systems. This normative activity would mitigate the overall

5 See http://www.oas.org/CDMP/
6 The concept of RADAR was first presented in two FAO reports (Borgia, 2000 and 2001).

impact of disastrous events not only by improving emergency interventions, but also by improving disaster preparedness and integrating risk and hazard awareness into long-term agricultural development planning.

It should be noted that the twin aims of rapidity and of accuracy here are in part in conflict with each other, but tools are to be developed to optimize accuracy in assessing damage within the shortest possible period. Also, real-time adjustments of the assessment, reflecting information flow from field and other sources, allow for continuing optimization of impact assessment and emergency management.

Three elements interact in the design of the complex system that is RADAR, so that it can serve to support the decision-making process at the national level. Ignoring any one element may limit the usefulness of the system and create obstacles for its implementation and practical use. The three elements are:

- **Problem definition** Clear and unambiguous definition is needed of the problem, its distinct components and their interrelationships.
- **User identification** Characterization of input, processing and output requirements.
- **System design** Integration in a flexible, real-time updatable system within the emergency-management environment of the user.

These elements can be incorporated in the system for RADAR by adopting a rationalized description of the environment and the disaster through a conceptual model that comprises:

- **a modular system** designed around the parts of the problem. Modules perform clearly defined tasks that are less subject to change than the technology to perform them. Modularity allows the system to be more flexible and easier to update;
- **object-oriented procedures** that reflect the topological (spatial) structure of the problem; and
- **model-oriented implementation** based on icons and operators, to allow an adequate degree of abstraction, flexibility and rationalization while avoiding being overwhelmed by large amounts of non-critical data.

Finally, it is important to point out that in integrating this system particular attention should be paid to the work environment of the user and the institution. People who work on disaster impact assessment in agriculture and use impact assessment data should be included in the team when defining the project specification of a DSS. Reliable local contacts need to be established as soon as possible to provide flow from the field of information for damage evaluation and rescue management.

1.2 DEFINITIONS

In disaster-related literature some commonly used terms are frequently ill-defined or have different, sometimes conflicting, definitions. Whenever possible definitions used here comply with the Glossary of Disaster Management (UNDHA/IDNDR, 1992). Appendix 1 mirrors these definitions in quantitative terms and lists all commonly used specific terms. Definitions for key words are provided in Tables 1.2, 1.3, 1.4 and1.5 at the end of section 1.2.1.

1.2.1 Event and disaster

An **event** is a relatively short-lasting, high-amplitude phenomenon that is accompanied by *degradation* of the *milieu*. A **disaster** is the general outcome of an *event,* and corresponds to a significant disruption of the normal life of at least the smallest human *community*.

The underscored words are fundamental to this definition because they constrain the lower limit or the *minimum damage* level required before a recorded event can be considered a "disaster". Accurate quantitative definitions of lower limits need to be identified according to the peculiarities of the natural and social components of the milieu, and may be perceived differently depending on cultural and socio-political settings. Thus, the definition of significant, normal and smallest should be validated by a specific person or team at a high level of authority.

The process of impact assessment can be started only when it has been decided that a phenomenon is (or could be) an event. Taking this decision has a large element of arbitrariness due to lack of reliable information. It is frequently possible to postpone the decision to a later stage in the process of impact assessment; in the interim, the event is called a **presumable event**. In the case of an estimate of the impact of an event that is expected to occur, but has not yet occurred, the event is called a **potential event**.

The assessment of the disaster impact may be restricted to an evaluation of the percentage loss of value for each component within each *parcel* of the *area*. In turn, these losses may be appropriately combined to obtain the toll of the disaster (or its negative impact). The overall advantage of such an approach is fourfold:

- impact evaluation can be standardized;
- it is easy to calculate;
- it is verifiable; and, perhaps most importantly,
- the impact assessment can be updated in real time, as data become available.

The sum of the damage of all parcels is the damage in the *area* and corresponds to the assessment of the environmental *disruption*, i.e. the *toll* or negative *impact* of the event in that area. The damage has the same dimensions as the value. To compute the damage of a component after *N* contiguous disastrous events, it is sufficient to find the percentage loss in the actual value after each disaster, *n*. This value is the residual value after the disaster multiplied by a **recovery factor**. The recovery factor is needed because some of the damage may be mitigated (or aggravated) in the lag between two subsequent events.

TABLE 1.2

Main characteristics of an event

Duration	The time interval between the normal condition before and after the phenomenon.
Amplitude	A quantitative measure of the maximum energy per unit time associated with the event.
Magnitude	A quantitative measure of the total energy of the event.
Local magnitude	The quantitative energy locally associated with the event; it is a function of the local duration and amplitude of the event.

TABLE 1.3

Area of impact and community affected [7]

Region	An arbitrary part of the surface of the Earth where an event has occurred or it is foreseen to occur. It includes all geographical, natural and social aspects, and it may extend across cultural and political boundaries.
Area	Part of the region where the evaluation of the impact of a disaster is to be conducted (excluding off-limit territories where the impact cannot, should not or does not need to be evaluated).
Parcel	Conveniently small fraction of the area that may be considered to have uniform values for the properties of the components of interest. Attributes may be the value of the components of the milieu of the parcel, the percentage loss of value, etc.
Community	Comprises the people that are related to an area. The community may extend beyond the people that reside in the area, due to knock-on effects, such as food supply or labour deprivation in neighbouring areas.

[7] Note that "area" and "parcel" as defined here are dimensionless. To obtain the extent of an area or parcel, it should be multiplied by the topographic surface area.

TABLE 1.4

Environment and element, milieu and component

Environment	Natural and socio-economic elements (broad)
Element	Part of the environment (broad)
Milieu	Includes all natural and socio-economic components that are of interest for the impact assessment
Component	A specific part of the milieu of a parcel (characterized by a value)

TABLE 1.5

Value, percentage loss, degradation and disruption

Value [8]	Quantitative definition of the importance that every component of the milieu of a parcel has for the community prior to the event (as monetary or any arbitrary or absolute units).
Percentage loss	The measure of how much the value of the component is reduced or how much the component has been degraded, after "recording" the event.
Degradation	The areal distribution of the percentage loss produced by an event on the environment.
Disruption	Comprehensive negative influences of an event on the environment.
Impact	Both positive and negative (toll) influences produced by events on the environment.
Toll	The negative influences produced by events on the environment.
Damage of a – Component – Parcel	 Product of the value and the percentage loss for that component. Sum of the damage of all components of the milieu of a parcel.

[8] The quantification of the values is a very delicate part of the impact assessment. Communities are always very sensitive to values, and some components may have historical or cultural values that are difficult to valuate.

1.2.2 Intensity of an event

The **intensity** of an *event* is an empirical quantitative measure of the degradation produced by the event in any given parcel. Therefore, it is not a simple direct function of the event type or magnitude. The **component intensity** is defined in general for each *component* of the *milieu* of a *parcel*. Then, the intensity of the event in a parcel becomes the weighted average of the components intensities.

The local *magnitude* may be related to the *intensity* of an event by *'transfer functions'* based on past experience or calibrated modelling, or by more empirical functions that relate local event energy to degradation of parcel components. In the same way, a direct relationship (or transfer function[9]) exists between *intensity* of an event and *percentage loss*.

It is important to note that the intensity of the event is neither the damage, nor the magnitude or the percentage loss. For instance, a parcel of wheat may be flattened to the ground by a storm of a certain local magnitude. Depending on the vulnerability level of the component when the event occurs, the plants may be uprooted or not and the intensity of the event may be high or low, respectively, for the same event magnitude. And the same event may result in different percentage losses and damage, depending on how much the plants may be allowed to recover.

The transfer functions are, in general, part of the knowledge necessary for disaster impact assessment – knowledge that should be accumulated within the knowledge-base. Direct measurement of the component intensity (for instance, by visiting the disaster area), would allow for higher accuracy in the computation of the percentage loss for each component, when compared with the intensity of the parcel *generated* from the local magnitude of the event.

1.2.3 Hazard

Hazard is the potential or probability of occurrence of an event, of a given magnitude, in a defined region and time interval. The definition of the **time interval** is a fundamental, but arbitrary, part of the evaluation of the hazard, which depends in turn on a large number of factors, including cultural and political aspects. It can be taken as the recurrence time of major events, such as about 10–100 years for tropical cyclones[10] and tornadoes, 100–1000 years for floods, droughts and earthquakes; about 1 000–10 000 years for volcanic eruptions; and

[9] An example of transfer function can be found in Palmieri et al. (2006).

[10] Tropical cyclones have various names, including typhoons (Asia) or hurricanes (North America).

even up to 100 000 years for hazards related to industrial accidents involving nuclear repositories. It is possible to choose the time interval based on the life of infrastructure, usually about 50 years, or based on consideration of how the danger of the event is perceived by the community. Other criteria could be based on legal or insurance issues. A useful choice is the average, weighted by their values, of the lifetimes associated with the components of the milieu in the area of interest.

Frequently, an event may trigger another event or a chain or tree of events. For instance, tropical cyclones may induce flooding, and that flooding in turn lead to landslides. These indirect events can generate additional damage, which may well exceed that of the first direct event and may also extend beyond the boundaries of the original region of interest.

The relation between the hazard of direct and indirect events may be described by a **probability tree**, in which the "trunk" element (order 0) contains the probability of occurrence (hazard) of the direct event. The first set of "branch" elements contains the probability of occurrence of the first set of indirect events (order 1), which are generated by the direct event. The second set of "branch" elements contains the probability of occurrence of a second set of indirect events (order 2) that are activated by the first set of indirect events. Thus, the hazard of an indirect event of order n along the branch chain is given by the product of all elements along the same branch chain going backwards from that indirect event to the original direct event.

Knowledge of the probability tree has to be incorporated in a rapid impact assessment in order to avoid biases from not having included the impact of these indirect events or for not having considered the preventive measures that could still be taken to reduce their respective impact.

1.2.4 Vulnerability and risk

Vulnerability is the potential percentage loss of value of each component of the milieu within a parcel, for an event of given type and magnitude. Once the event has happened, the hazard becomes unity, and the vulnerability (potential percentage loss) is replaced by the actual percentage loss.

Risk[11] is measure of the prospected damage of a potential event of a given magnitude in a given area and time interval. It is the integral of the product of the value and its vulnerability over all components of each parcel in the area, multiplied by the hazard.

[11] If the risk is higher than the *minimum damage*, then preventive measures may be implemented (i.e. invoking *preparedness*) to reduce the effects of a potential *disaster*.

1.2.5 Errors

Poor accuracy may drastically reduce the usefulness of the impact assessment. In many cases the sources of large errors are few and can be substantially eliminated by improving procedures for data collection and elaboration. In practice, the measurement of quantifiable parameters, such as *value*, *percentage loss* and *hazard*, is affected by errors usually estimated with standard empirical or statistical approaches. In turn, the quantities that are computed from these parameters will be themselves affected by errors that can be estimated by propagating the original errors with standard statistical procedures. Other errors are more deceptive and difficult to quantify. They arise from definition of the area of the region, the number and extent of parcels, and the number of components of each parcel. These errors should be identified and quantified by trial-and-error procedures guided by past experience.

CHAPTER 2

DISASTER INFORMATION MANAGEMENT SYSTEM

The purpose of an information management system for *agricultural disasters resulting from 'extreme'*[12] *factors* is of course, to identify patterns of event impacts on agriculture, with a view to improving impact assessments, forecasting and mitigation, including the adoption of regional planning and management of emergency operations, whenever feasible. The proposed system is thus to be seen essentially as an operational tool.

The RADAR concept relies on the analysis of the interaction of the components of the agricultural environment with an extreme physical event. Based on degradation of the milieu components, the total damage or the negative impact is computed. In other words, the event impact in terms of loss is the difference in value between an initial situation and the final situation after the event (including secondary effects).

2.1 EMPIRICAL ANALYSIS AND MODEL ANALYSIS

2.1.1 Empirical analysis

Empirical analysis collects post-event data directly in the affected area in order to evaluate event intensity. This approach is based on a statistically adequate sampling of components of the milieu in the area. Empirical analysis usually includes direct collaboration with local authorities and communities. Culture-dependent components can thus be factored in and influence the evaluation of event intensity. *In situ* observation of the degradation may allow for a better choice of those milieu components that more appropriately record or reflect the intensity of the event.

For instance, some components may be totally destroyed (*thus, their recording of the intensity of the event is not possible, i.e. it was "saturated"*) or not affected (*thus, the intensity of the event was not sufficient to be recorded*). Both these

12 In its meaning in statistics, i.e. rare, infrequent.

types of component are irrelevant for the measurement of intensity. They are nevertheless relevant for calculation of the value loss or damage.

In practice, a significant number of components should be used for each parcel when measuring intensity, although in principle only one component of the milieu of a parcel is necessary. To measure the intensity of the event within the parcel one should choose those components that have been only partly damaged. This generates sufficient data redundancy and overlapping to reduce error in measuring the intensity.

Empirical analysis is also used for feedback and to tune the various tasks performed during the first definition of the event. In fact, quite frequently, the amount and quality of the information used in defining an event immediately after it has happened is minimal. Therefore, the need for feedback is essential, particularly in the case of events that have been defined as presumable.

2.1.2 Model analysis

The integration of all relevant components into a Disaster Information Management System (DIMS) allows more efficient management of the impact assessment. The procedure of rapid impact assessment implies the use of physical models, knowledge-bases, databases and GIS.

- **Model-Bases** (MB) are generally physical models developed to determine the local magnitudes of events.
- **Knowledge-Bases** (KB) are used for transforming local magnitudes into intensities and linking intensities to percentage losses by means of transfer functions constructed on historical knowledge.
- **Databases** (DB) contain all collected data to be used throughout the process, and in particular for the computation of damage.
- **Geographical Information System** (GIS)[13] technology allows the integration of MB, KB and DB through spatial and temporal referencing of information and data.

MB contains the mathematical models (analytical, statistical, analogical, numerical, etc.) that simulate specific aspects of the geophysical phenomena under consideration. They may require different degrees of accuracy in data input (ground observations, remote sensing, etc.) and produce results with variable approximation. In some cases, more than one model could be activated

[13] GIS software provides the functions and tools needed to input, store, manipulate, analyse and display georeferenced information.

to use available data effectively and produce reasonably accurate results in the shortest possible time. Model results should represent, with relative accuracy, the area distribution of the local magnitudes of the event.

There are two KBs that contain information needed for the design of transfer functions. The first set is used to assign intensity values to parcels, given the local magnitudes; this transfer function is event and milieu dependent. The second set is used to assign the percentage loss to each component of the milieu, given the local intensities. Both sets of KB are collected by comparing local magnitudes to intensities and intensities to percentage loss, respectively, in similar previous events. In those previous events the intensity and the percentage loss should have been determined directly in the area from the degradation of the milieu components. Empirical, procedural, heuristic and algorithmic relations, extracted from this comparison, form the KB. Finally the KB should be combined with a decision-support system (DSS) for assisting the transfer.

DB stores all relevant information associated with the region, area, parcels and components of the milieu for each parcel of each event. This information is best organized in a GIS-associated relational database, because of its intrinsic temporal and spatial dimensions. In particular, the values and percentage losses for each component of each parcel in the event affected area should be incorporated into the DB to enable calculation of event damage.

The GIS should be considered as the platform on which the impact assessment of a disaster will be computed. MB, KB and DB are all integrated into the GIS, for both data input and output. In fact, the procedure for calculating any impact-related parameter from the original data maintains its geographic nature, as does the data itself. In particular, one of the results of the assessment must be the area distribution of damage (illustrated graphically in map form) produced by a disastrous event.

In spite of the fact that the definition of the most appropriate hardware and software needed to implement the DIMS is premature, recent technical developments in personal computers and associated off-the-shelf programs are adequate for the task and are strongly recommended for such use. Of course, the MB and the two KBs need to be set up in advance, using historical data, prior to performing the impact assessment.

2.1.3 Conceptual model of impact assessment

In most cases, it is not possible to represent with clarity the complexity of the event: the data characterizing the milieu (topographic, hydrologic, agronomic, etc.); the event (magnitude, area, etc.); as well as real-time (current) monitoring information. All this information could overwhelm the output. In addition, there are many areas in the world for which there is no adequate geographic data cover, precluding the use of the GIS to its full potential.

Therefore, it is convenient to define an abstract (conceptual) model of the impact assessment problem. In no way is the conceptual model a surrogate for the GIS model. To the contrary, they are complementary, and, whenever possible, they should be developed concurrently. The conceptual model is designed to show the structure and solve specific problems related to a territory. In addition, it is one of the essential components for the future development of a DSS.

The conceptual model is designed to represent – in a symbolic way – the actual problem, with its relevant components, eliminating all unnecessary or redundant information. The conceptual model reduces the problem to the interaction among objects, each object representing a well-defined aspect of the problem. For instance, region, area and parcels are *geographical objects*, while the relations between parcels are *operational objects*. The simulation of events may be represented by *model objects* and the transfer functions by *knowledge objects*; the impact assessment itself is a *surveying object*.

In Part B of this publication there is a simple example of building up a conceptual model representing the physical model of a disaster region affected by Hurricane Mitch in Honduras (Section 6.7).

Once the conceptual model is designed and implemented, it can be used very effectively to test different DBs and approaches for impact assessment. Elements of the model and their interactions may be modified easily, such as by activating or de-activating data links, including or excluding parcels, changing values in the DB, or using different models.

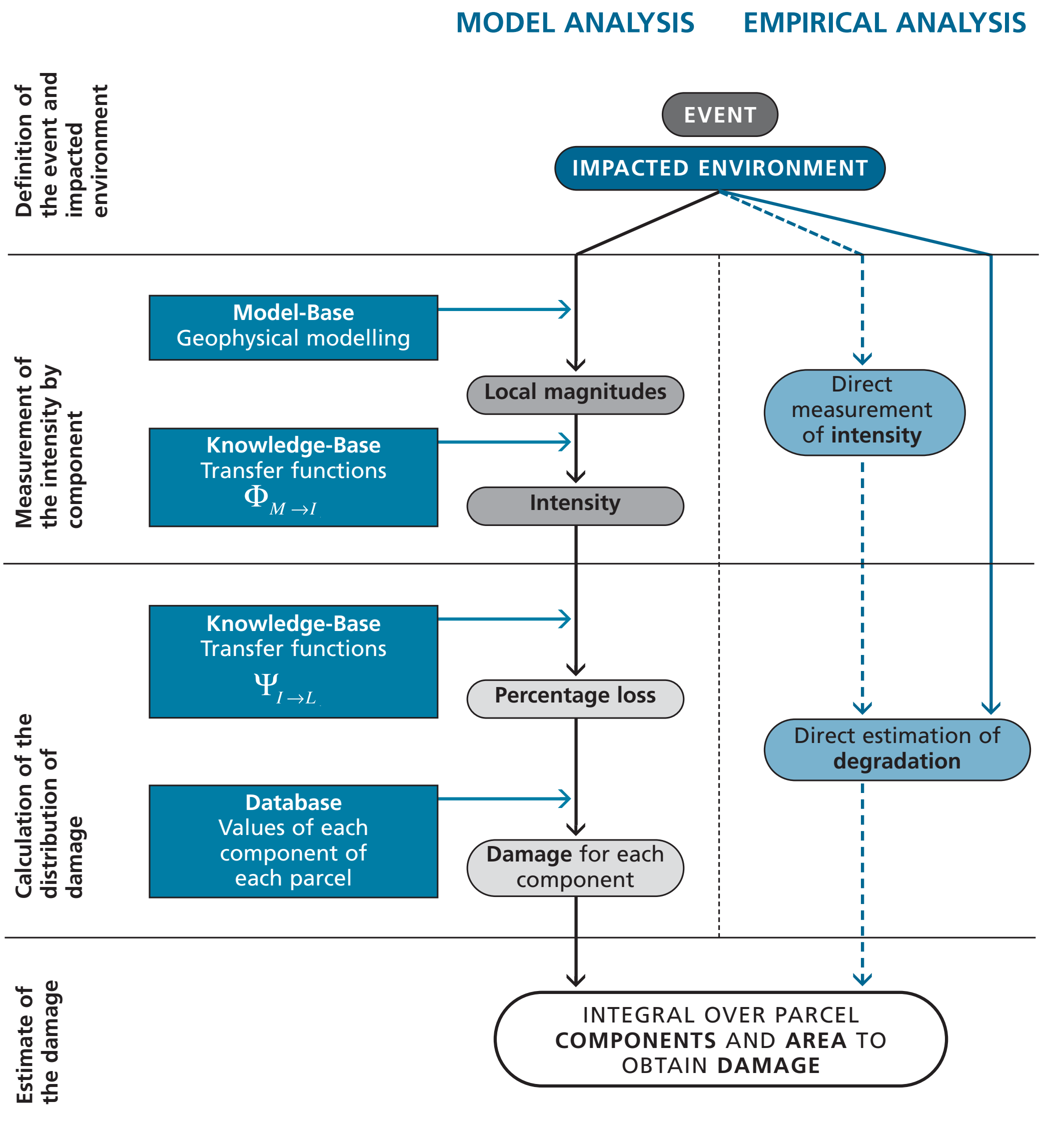
A well-designed conceptual model may also be used, with some limitations, beyond the group of experts that set up the model. It might be used to evaluate risks originating from real hazards, or from hypothetical situations. It could serve as a tool for training personnel in impact assessment or for evaluating recovery operations.

2.2 FLOWCHART OF THE ASSESSMENT ROUTINE

The assessment of the impact on agricultural systems of a disastrous event might follow a procedure that can be defined precisely, at least for the major steps (Figure 2.1). For a rapid assessment, one of the components that comes into play is the degree to which the step-by-step assessment procedure is clearly defined. This procedure assumes that a DIMS (see Section 2.1.2) already exists. The DIMS contains all geographical, historical and model data on events and affected systems, in addition to the related MB, KB and DB. In practice, when a disastrous event strikes a region, one must rapidly collect all relevant available data on the event and the region. The immediate and long-term impacts are then projected using the DIMS to its full potential. Note that both speed and accuracy in impact assessment may improve with time, as more data are integrated within the DIMS. More specifically, to assess the impact, four major steps need to be completed.

FIGURE 2.1

Schematic process flow chart



They are:

- definition of the event and the impacted environment;
- measurement of the intensity of the event;
- calculation of the distribution of damage; and
- evaluation of the damage.

Each proposed major step and sub-step is described in the following sections. It is assumed that a disastrous event has taken place and that some information about the phenomenon has already been made public. Of course, the model base and the two knowledge bases need to be set up in advance, compiling historical data, prior to performing the impact assessment.

The first step in the process of impact assessment is the decision that a phenomenon is, in fact, a disastrous event. As indicated above, if insufficient data are available this decision may be postponed to a later stage in the assessment process. In this case, the event is only presumable and the assessment process may be interrupted at any stage.

Physical data of magnitudes and area distribution of the main phenomena and associated sub-phenomena are collected from various sources, where relevant, including satellite imagery and ground measurements. In the absence of a map layer at the appropriate scale, satellite images could be transformed into basic map material. This process corresponds to the definition of a physical model, which is based on the actual geography of the area.

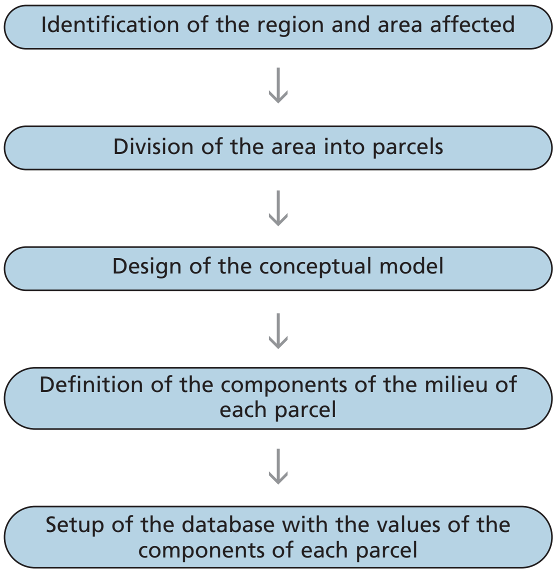
It is necessary to identify the region of impact of the event and the area in which the impact should be calculated. In turn, the area should be subdivided into parcels that have constant properties for the components (or a similar milieu in each parcel).

For the characteristics of parcels and main components, different sources of information are consulted:

- existing special-purpose maps: soils, topography, vegetation, land use, farming systems, population densities;
- annual reports on component performances (regional level);
- technical reports: research and development;
- satellite imagery: component characteristics (crops, planting period, physiological stage, areas); and
- a basic topographic map (at a suitable scale).

Finally, the value of each component should be loaded in the DB, taking into account links and interactions between components of different parcels. See Figure 2.2 for a flowchart of the definition of the impacted environment and Sections 3.1-3.3 for more discussion on the definition of the event and environment.

FIGURE 2.2
Definition of the impacted environment



The second step is the measurement of the intensity by components. As noted above, there are two approaches to assessing the intensity of the event in each parcel: through **empirical analysis** and through **model analysis**. The empirical analysis is done *in situ*, whereas the model analysis is done *ex situ*. Although model analysis is usually more rapid and directly integrated into a GIS, it is less accurate than empirical analysis, especially when the area is easily accessible. Depending on the local situation, both approaches may or may not be applied concurrently. The model analysis could also be used to guide the empirical analysis, while data collected *in situ* enrich and gradually refine the model's output. Experience over time will allow for gradual model (or model combination) adjustment and performance improvement. Both analyses produce a map of the area distribution of the intensity in the area (see later, Section 3.4).

The third step is calculation of the distribution of damage. Once the spatial distribution of the intensity is known, the functions contained in the second KB transform the intensities into percentage loss (damage) of the components of the milieu of each parcel (further elaborated in Section 4.1).

The last step is calculation of the damage. Subsequent combination of the percentage loss with the values of the components, derived from the DB, allows a calculation of the value loss (the damage) for all components of each parcel. The calculation of the damage of the area is then straightforward and corresponds to the integral over all parcels of the damage of the component of the parcels (see Section 4.2-4.3). This damage may be considered as an estimate of the impact of the event in the area.