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Rapid Agricultural Disaster Assessment Routine (RADAR)

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Rapid Agricultural Disaster Assessment Routine
(RADAR)

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FOREWORD

Globally, the number of natural disasters, the number of people affected and the impact of disasters are increasing. More than 250 million people have been directly affected by disasters every year since 2000; the highest figures ever recorded, according to the Centre for Research on the Epidemiology of Disasters (CRED). Developing countries in Africa and Asia are particularly vulnerable to extreme atmospheric factors and climate-induced shocks. Recent major disasters, however, such as earthquakes in Java (2006) and Kashmir (2005), Hurricane Katrina in the United States (2005), the Indian Ocean tsunami (2004) and severe heat wave in Europe (2003), have shown how vulnerable any country in the world is to the loss of human life and livelihoods due to natural disaster.

FAO assists countries in reducing disaster-related risks by providing early warnings of food production emergencies and helping to restore food production systems in disaster-affected areas. Agricultural disaster impact analyses most often used to plan emergency relief operations are typically based on *in situ* empirical analysis, dependent upon access to the affected area and expert experience. The urgency of emergency situations, however, often prevents the collection of sufficient georeferenced information. The effectiveness of emergency assistance depends on timely and accurate assessments of disaster impacts, supported by sufficient quantitative information.

This publication introduces the Rapid Agricultural Disaster Assessment Routine (RADAR), a rapid disaster impact assessment tool for agriculture. The overall objective of RADAR is to provide a practical decision-support model for rapidly and accurately assessing the georeferenced area distribution of short- and long-term damage on agricultural systems due to natural disaster. Successful implementation of RADAR could improve disaster preparedness, facilitate timely relief operations and integrate risk and hazard awareness into longer-term agricultural development planning.

FAO believes that implementation of RADAR will help to understand more rapidly and accurately how specific geographic areas will be experiencing short- and long-term damage, due to natural disaster. RADAR is one example of the type of technical assistance necessary to improve preparedness and early warning systems to strengthen the resilience of vulnerable populations. We sincerely hope that RADAR will help improve the efficiency and timeliness of relief operations and reduce human suffering caused by natural disasters.

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ABSTRACT

Agricultural disaster impact analyses used for planning emergency operations are mainly based on empirical *in situ* analysis, and largely dependent on access to the affected area and on experts' experience. Not only are disaster impacts difficult to model but emergency situations often prevent sufficient collection of detailed georeferenced information, which would allow the calibration of impact models. Moreover, the urgency of relief operations hampers the development of necessary tools.

The Rapid Agricultural Disaster Assessment Routine (RADAR) is based on the idea that a disaster is the "product" of extreme factors and a vulnerable agricultural system. The current state of agricultural systems can be routinely collected in an information system. For extreme factors of geophysical origin, detailed quantitative and georeferenced data about their characteristics are known almost immediately after the event. Some pre- and post-impact data are also rapidly available through remote sensing. If impact models were readily available at the time of a disaster, this set of knowledge could be used to model impacts and to generate preliminary assessments very rapidly.

Part A (chapters 1-4) of the RADAR report proposes to move from empirical assessments towards model approaches. Once an event strikes a region, the user of the procedure should rapidly collect all available georeferenced and quantitative data on the event and the region. Subsequently, a Disaster Information Management System (DIMS) that integrates physical models, knowledge-bases, databases and GIS can be used to assess the short- and long-term agricultural impact of the event.

The procedure combines model analysis, based on physical simulation of the disaster, and empirical analysis, using people's records of the environmental disruption after the event. Both analyses may be used alone or concurrently and they can be updated in real time to improve the assessment. The output of the analyses is the geographical distribution of the intensity of the event, which is then used to compute the integrated impact (the loss) to agriculture produced by the disaster.

RADAR is a very powerful support tool for decision-making during a disaster impact assessment. Full implementation of the assessment procedure in a DIMS allows a rapid and accurate assessment of the impact of disastrous events on agriculture. Impact forecasting and updating using on-ground and satellite remote sensing data inputs are also resorted to. In the medium to long term accumulated information and in-depth analyses should provide a significant contribution towards disaster preparedness and minimization of potential risks through early warning strategies and preparation of development plans that incorporate resilience to such disasters.

In Part B (chapters 5-8) the general approach of RADAR is illustrated by an example of the impact evaluation of Hurricane Mitch on the Honduran agricultural production system. The distributions of percentage loss and agricultural value per unit area are aggregated to calculate damage value for each region and each sector (forest, crop land, fruit trees, and pasture). The total impact is estimated to be about US$ 750 million with 8 percent error margin. Combining information derived from historical disasters with current remote sensing data input could improve anticipation of tropical cyclone system impact, and support actions to be taken both during and immediately following an event.

Rapid Agricultural Disaster Assessment Routine (RADAR)

By Andrea Borgia, René Gommes, Michele Bernardi and Hideki Kanamaru

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AN APPLICATION OF RADAR TO HURRICANE MITCH HONDURAS, OCTOBER 1998

ACRONYMS

CINDI	Centre for Integrated Natural Disaster Information
CRED	Center for Research on the Epidemiology of Disasters
DB	Database (as part of DIMS)
DIMS	Disaster Information Management System
DSS	Decision-support system
EM-DAT	OFDA/CRED International Emergency Disasters Database
ESS	FAO Statistics Division
EOC	Emergency Operations Centre
GIEWS	Global Information and Early Warning System
GIS	Geographical Information System
KB	Knowledge-Base (as part of DIMS)
MB	Model-Base (as part of DIMS)
NOAA	National Oceanic and Atmospheric Administration (USA)
OFDA	The Office of U.S. Foreign Disaster Assistance
R&D	Research and Development
RADAR	Rapid Agricultural Disaster Assessment Routine
USGS	US Geological Survey
WFP	World Food Programme

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

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[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

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[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

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[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.

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[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.

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[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

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[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.

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[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

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[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

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[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.

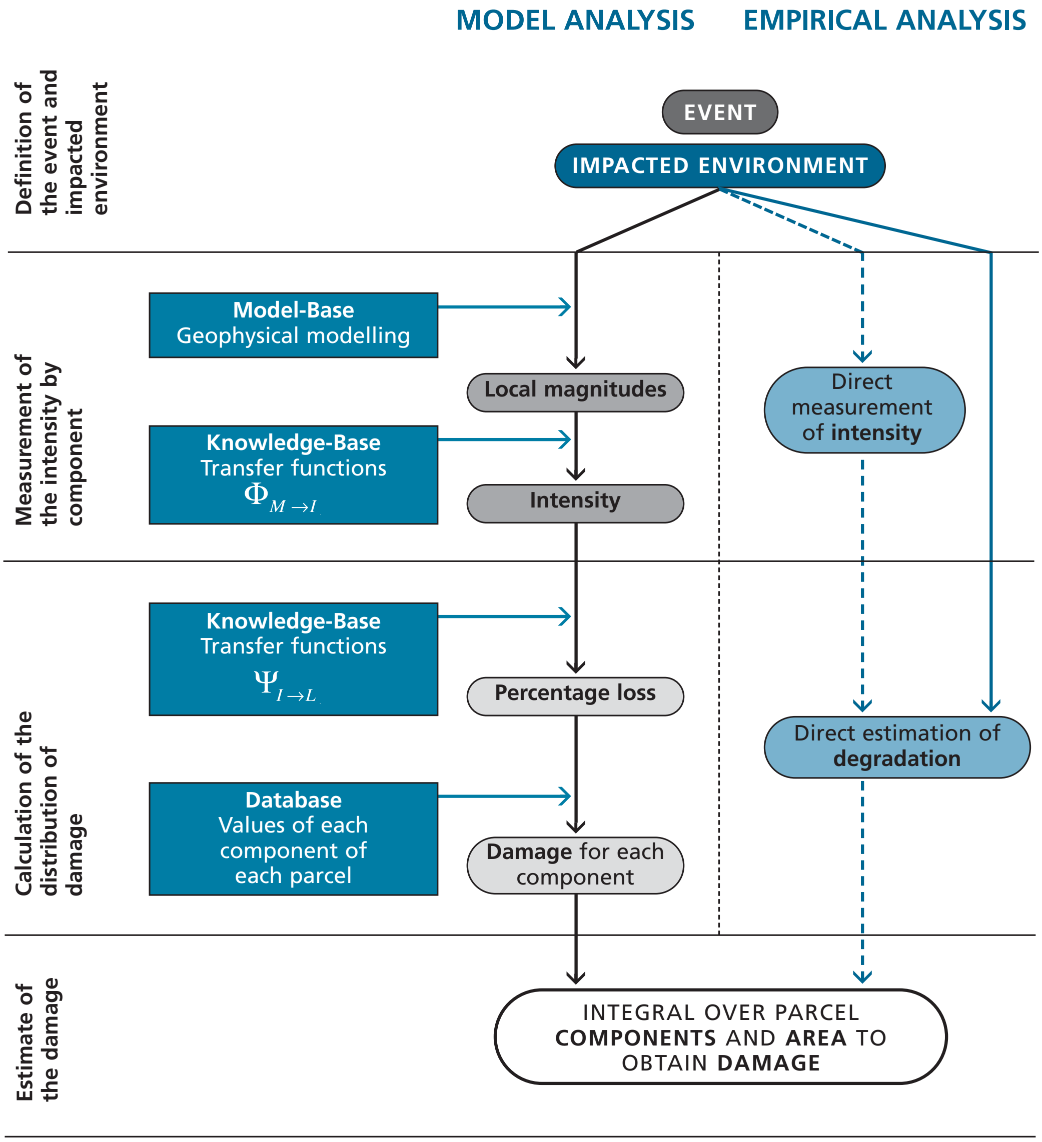
A well-designed conceptual model may also be used, with some limitations, beyond the group of experts that set up the model. It might be used to evaluate risks originating from real hazards, or from hypothetical situations. It could serve as a tool for training personnel in impact assessment or for evaluating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

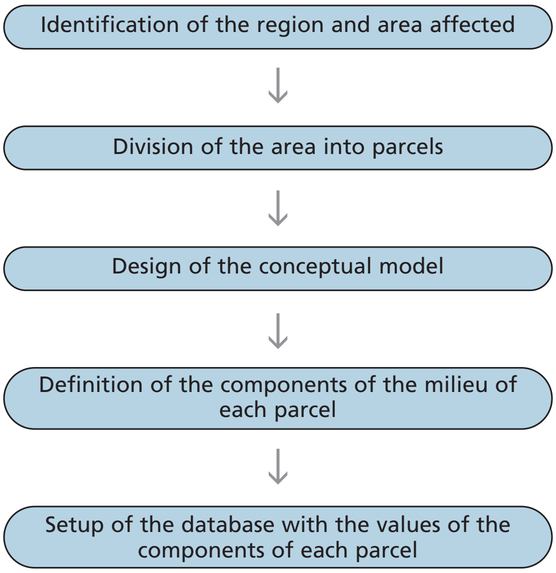
For the characteristics of parcels and main components, different sources of information are consulted:

- 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.

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.

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[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.

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[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.

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[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.

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[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.

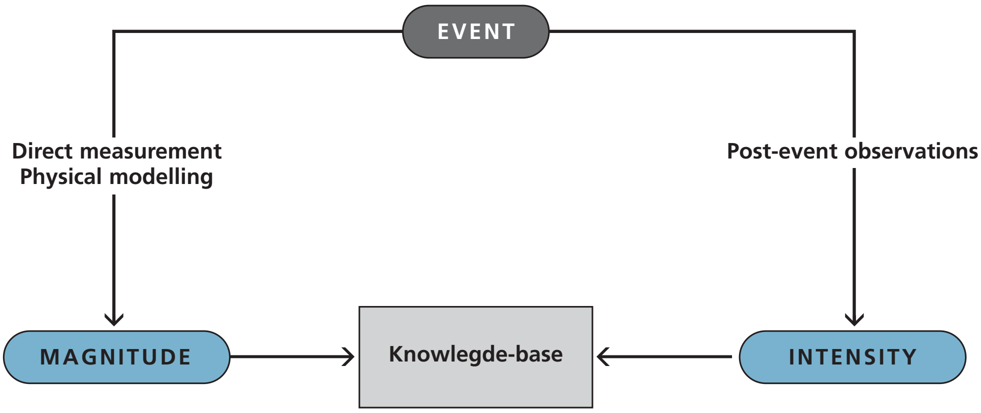
3.4.1 Magnitude

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.

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[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.

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[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.

PART B

AN APPLICATION OF RADAR TO HURRICANE MITCH

HONDURAS, OCTOBER 1998

CHAPTER 5

INTRODUCTION

A very strong hurricane hit the Caribbean coast of Honduras in the last week of October 1998. At the end of January 1999, about three months after the event, an FAO-WFP report on Honduras (FAO-WFP, 1999) concluded with the following:

> “Hurricane Mitch, which swept across Honduras, Nicaragua and neighbouring countries early in the week of 27th October [1998] is considered to be the worst natural disaster in recorded history to hit Central America. Honduras suffered more than its neighbours, because, after sweeping across the country, the hurricane became stationary off the Caribbean coast of Honduras, resulting in torrential rains, flooding and landslides that killed over 7 000 people and left another 8 000 people missing. In all about 276 000 families were affected by the hurricane and over 600 000 people were evacuated. In addition to the loss of life, extensive damage to infrastructure, including destruction of houses, roads and bridges, and severe damage to the agricultural sector were sustained. About 310 000 hectares were affected, with damage estimated at US$ 881 million. Losses, owing to loss of land fertility, have been estimated at US$ 400 million. ... The greatest hurricane damage occurred in the northern areas, where the hurricane entered the country, and along the path of the hurricane as it moved south across Francisco Morazan to the southern areas.
>
> “The mission observed two types of damage. First, major damage was concentrated along many river valleys, as the water levels rose to record heights. Second, landslides, which were localized, were common in upland areas and especially in deforested areas. The extent of the damage to crops and livestock varied greatly with location: from total destruction of some villages, which were in the path of rising flood waters or covered by landslides on steep upland areas, to only slight damage caused by heavy rains on the fringe of the hurricane. This great variation in the extent of damage presented the Mission with the difficult problem of estimating overall damage throughout the country. The damage was severe in some areas, but not total throughout the country.
>
> “The Mission’s evaluation of crop damage is based on field visits to hurricane-affected areas in the south (Department of Choluteca) and in the north of the country (Litoral Atlantico); discussions with government officials concerned (Secretary of Agriculture and Livestock, and Secretary of Finance) and representatives of the private sector (CONNPAH); meetings with donor representatives, including USAID and the

> European Union; and contacts with non-governmental organizations (CARE, CARITAS, Save-the-Children, and others). The Mission also met with other UN agencies, including UNDP, UNICEF and WFP, and with associations of producer cooperatives, which provided the opportunity to examine production trends, trade, stocks and other data. The Mission visited numerous markets in different towns and villages to assess the availability of food and to determine prices."

While the description above gives an adequate idea of the general nature of the disaster, it does not assess quantitatively the physical aspects of the event in various regions (Departments) of the country. For the impact of the hurricane on food security, a FAO publication provides a good summary (FAO, 2001).

In Part B of this report, a worked example of disaster impact assessment for Hurricane Mitch is described in detail to show the validity and practicality of the approach proposed in Part A. It should be noted that much of the data needed to adequately apply RADAR has never been collected and the present example can consider only a limited sample of the environmental elements involved in the region of impact.

CHAPTER 6

THE EVENT, ENVIRONMENT, AND MILIEU

6.1 DEFINITION OF THE PHYSICAL EVENT

One of the sources of general information that reports the physical aspects of the hurricane is the Centre for Integrated Natural Disaster Information (CINDI) of the US Geological Survey (USGS), which in collaboration with the National Oceanic and Atmospheric Administration (NOAA) gives an account of the event at 3–6-hour intervals. They report position, wind speed, pressure and the Simpson intensity scale for the hurricane (see Figure 6.1 on p. 71 for the hurricane path). Hurricane Mitch started as tropical storm in the southern Caribbean Sea on 22 October 1998, and headed north. After turning WNW at the latitude of the northern coast of Honduras, it became a scale-5 hurricane on 26 October, when it was 150 km north of the coast. As it turned south toward the land, it hit the Islas de Bahia Department of Honduras as a scale-4 hurricane on the 28th. The next day (29 October), it entered the northern coast of Honduras, rapidly decreasing in intensity from a scale-2 hurricane to a tropical storm. After sweeping across Honduras from east to west, it entered Guatemala on 31 October, continuing toward Mexico. Thence Hurricane Mitch headed north again to the Caribbean coast and then NE toward Florida, USA.

6.2 THE REGION OF IMPACT

The first step in the disaster impact assessment procedure is to identify the region and area affected by Hurricane Mitch. The definition of the region of impact is relatively simple once the extent of the physical event is known in adequate detail. A number of maps, in addition to the one showing the track of the hurricane, that describe in sufficient detail the region of impact can be found at CINDI. According to these sources, the region affected by Hurricane Mitch covers almost all Central America, including Costa Rica, El Salvador, Guatemala, Honduras and Nicaragua.

The infrastructure map shows that there is a fairly dense, homogeneous distribution of villages, apart from the Atlantic coast, where density decreases to almost nil. The largest number of main electricity power lines are located in Guatemala, Nicaragua and Salvador, with very few in Honduras, the country that was swept across from east to west by Mitch. Thus, to

attempt a first-order approximation, it is expected that most of the damage will be concentrated on the villages, roads and bridges of Honduras. Southern El Salvador, northern Nicaragua and Guatemala have also been affected, but with less impact.

6.3 THE AREA FOR IMPACT ASSESSMENT

The data presented in the preceding sections show that the greatest loss was suffered by the country of Honduras. Thus, one should limit the *area* over which to estimate the impact to that country. This decision is not irrelevant, nor obvious, and a similar study could be implemented for areas affected in Nicaragua or Guatemala. The choice of this area is a compromise forced by the fact that agricultural production DBs are structured by country and also often by Departments within a country. Production is averaged over countries (and departments), and therefore there are no point-specific sources of information on agricultural production, which would be the optimal data set.

In fact, there is a dichotomy between the actual physical data of a destructive event, which can be obtained, in principle, spatially over the whole region of impact through a point-specific structure, and the agricultural production data that is usually stored by discreet surface units (either by country or by Department). This dichotomy would not be a problem if each surface unit (country or Department) were affected in the same way and intensity by the same type of event, which is of course highly unlikely.

Once the area of Honduras has been identified for the impact assessment, a number of data and thematic maps could be obtained from a CD produced by USGS-CINDI and the Honduran authorities. This data set is relatively extensive and includes area and population data by Departments, but also holds available agricultural production statistics by Department over the 1990–94 period, at least for the main crops.

6.4 COMPONENTS OF THE MILIEU

6.4.1 Agro-ecological zones

The general map of the ***types of vegetation*** shows that the territory affected is in the tropical evergreen and deciduous forest climatic zones, plus a smaller amount of wet savannah. In fact, a significant part of this territory is used for agricultural activities, as cropping or grazing land. Thus, in general, it is expected that, because of Mitch, much damage will be suffered by the agricultural sectors.

6.4.2 Potential land use and farming systems

The data on Honduras from CINDI-USGS contains an ArcView shape file that shows potential land use. This data set is characterized by extensive subdivision of the territory into areas with different kinds of vegetation and potential use that is far more detailed than is needed for the purposes of RADAR. At the same time, the data set gives no information on actual land use and on crop distribution in 1998, which is the kind of information that effectively would be needed. Thus, the different subdivisions of the potential land use data set can be grouped into five major categories (Figure 6.2 on p. 72):

- **Agua** [water] is areas with permanent water on the surface that contribute nothing to the impact assessment if we are to exclude fishery from the impact assessment.
- **Bosque** [forest] is areas occupied by primary and secondary forest, or left to natural regrowth.
- **Cultivo** [crop land] includes the areas that have seasonal crops (such as maize, rice and dry beans), and also production that tend to be longer term or continuous (such as plantain and banana[22]).
- **Frutal** [fruit trees] includes areas planted with fruit trees and other perennial crops with seasonal production (e.g. orange and lemon groves, coffee or cocoa plantations).
- **Pasto** [pasture] includes all the grazing land dedicated to pasture for livestock (mainly dairy and cattle).

The groups identified above are only a first gross approach towards the precise mapping of the surface distribution of the agricultural production exposed to a disaster, which is what would be needed for disaster impact assessment. One can observe, for instance, that in the proposed land use map, *frutal* areas are almost completely limited to the southern part of Honduras, while in reality fruit trees are more evenly distributed throughout the country. Therefore, since the FAO-GIEWS database[23] contains data for fruit trees in all Departments, the GIS model needs to be adjusted by adding to the former set an artificial *frutal* parcel in those Departments that have none.

As already indicated, the potential land use map, being the only available indication of crop distribution, is one of the elements that limits accuracy in the present impact assessment.

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[22] Since bananas and plantains are harvested over several cycles, without replanting, these crops could also be considered as semi-perennial.

[23] http://www.fao.org/GIEWS/english/index.htm

6.5 THE PARCELS FOR IMPACT ASSESSMENT

The definition of parcels for the impact assessment is a complex task. There is no “correct” or optimal solution to this problem. By definition, a parcel is a fraction of the *area* that may be considered to have equal or similar property values for the milieu components under consideration. Generally, the level of precision for parcel definition is constrained by the form, structure and availability of component-related data.

More specifically, the dichotomy between spatially distributed physical data of the destructive event and agricultural production data, stored by administrative units, is unavoidable. The physical model of the area of impact will be based on the GIS data layers, while agricultural production data, such as obtained from the FAO-GIEWS database, will be stored on a Department-specific basis. In practice, the map of the administrative units will be superimposed with the modelled rainfall map, the flooded areas map, and the potential land use map. The result is a set of 123 parcels (Figure 6.3 on p. 72) that are homogeneous in three parameters: each one belongs to just one Department; was damaged from the same type of event; and has the same nominal land use. The parcels that are small, that is less than 1000 ha, may be an artefact of the GIS elaboration; they are, in any case, too small to contribute significantly to the impact assessment and are neglected. Also, parcels consisting of surface water do not contribute to the impact assessment and can be assigned an impact of $ 0. Thus, the working set is reduced to 103 parcels. For each of these parcels, the total area (ha), the number of villages and the population are known.

6.6 THE COMPONENTS OF THE MILIEU OF EACH PARCEL

In the present example, there are five parcel categories (*agua, bosque, cultivos, frutal* and *pasto*). For each parcel type, various components of the milieu need to be evaluated in relation to hurricane impact. To characterize the components of the milieu, the relevant elements are identified by system for each parcel (Table 6.1). *Agua* has been ignored as being of no significance for the present purpose.

The proposed component choice is presented mainly to illustrate an application of RADAR to a real case. It is not the only possible one, nor absolutely optimal, but is a compromise between the peculiarities of the area affected and the information available on agricultural production.

6.7 CONCEPTUAL MODEL

The parcels, once defined, are then used to construct a conceptual model of the area. The model is made by using the elements from a menu of tools. These

TABLE 6.1

Parcel characterization by system category

PARCEL TYPE Bosque	 Cultivo	 Frutal	 Pasto
Resource Systems			
Soil	Soil erosion and sedimentation	Soil erosion	Soil erosion and sedimentation
Trees			
Labour and habitat	Labour and habitat	Labour and habitat	Labour and habitat
Activity Systems			
Timber extraction	Bananas, Plantain, Maize, Rice, Beans (dry), Soybean, Cassava, Potato, Melon, Onion (dry), Sugarcane, Leaf Tobacco	Cocoa, Coffee, Oil palm	Cattle, Dairy
Support Systems			
	Farm buildings	Stores, greenhouses	Cowshed, farm buildings
Machinery and tools	Machinery and tools	Machinery and tools	Machinery and tools
	Input supply (fertilizer, etc.)	Input supply (fertilizer, etc.)	Input supply (feed, etc.)
Access infrastructure	Access infrastructure	Access infrastructure	Access infrastructure
Marketing system	Marketing system	Marketing system	Marketing system
	Agricultural R&D	Agricultural R&D	Agricultural R&D
	Financial services	Financial services	Financial services

elements are icons representing the region, the area, the various parcel types, event intensity, and data links between parcels (Figure 6.4 on p. 73).

The reality of the physical model is simply constructed by generating and positioning the elements over a board. For the Honduras example, given that the agricultural data is structured by administrative units, it is convenient to arrange icons by type and intensity for each Department. Every icon corresponds uniquely to a parcel (Figure 6.5 on p. 73). Thus, by clicking on an icon, one can access the data corresponding to that parcel, for both data input and analysis. The use of the conceptual model, with its much higher degree of abstraction than the physical model, facilitates the management of tasks needed to perform the assessment; the graphic presentation also simplifies its use by non-experts. The model automatically performs calculations, modifications and verifications of impact assessment as needed.

CHAPTER 7

CHARACTERISTICS OF THE EVENT

7.1 CAUSES OF DAMAGE

During the process of impact assessment of a natural disaster, it is of great importance to understand correctly the causes of damage and the interaction of the causes in producing the final damage extent. A careful study of this aspect (clarity of understanding) may frequently allow simplification of the general problem. For instance, if in a given area there is only a moderate destruction of crops due to strong winds of a storm but a total destruction is produced by flooding, the damage produced by the winds can obviously be neglected and only destruction generated by flooding needs to be considered. However, it is a good practice to consider damage produced by all concurring primary events such as wind, surge and spray. In the same way, collateral damage induced by secondary events such as rain, runoff, landslide, flooding, and sedimentation events, should also be combined.

7.1.1 Wind, surge and spray

The available information shows that the hurricane decayed rapidly from an intensity of 5 on the Simpson scale to that of a tropical storm as it approached the land. Wind damage was only possible in the Islas de Bahia Department and along the Caribbean coast of the Colon Department. In these two parts, flooding and torrential rains generated almost total destruction that masked the original wind-related destruction. Thus, in a first approximation, the effect of wind could be reasonably neglected for most of the agricultural impact assessment, although it should be considered in the evaluation of damage to houses along the coast outside the flooded area. Indeed, also in the Departments of Colon (close to the Atlantic coast) and of Islas de Bahia, areas that were not flooded may have been damaged by the wind.

Surge damage is also possible in the same coastal area, although the hurricane-related surge reached, according to the Simpson scale, a maximum of 2 m above the normal high tides on the Caribbean coast. The ultimate result of the surge is equivalent to that of an extremely high tide that inhibits the drainage of the rivers toward the ocean and increases the extent of flooding; thus, the damage produced by the surge is intrinsically incorporated into damage produced by flooding.

Finally, it is assumed that the salty ocean spray is rapidly washed away by the torrential rains, so no direct salt damage would be induced.

7.1.2 Rain, runoff and landslides

The average annual rainfall map (Figure 7.1 on p. 74) for Honduras shows that both the Atlantic and Pacific coasts normally receive about 1400–2000 mm per year of precipitation, while the centre of the region receives much less rain, with a minimum average precipitation of 400–600 mm per year.

The total precipitation map produced by NOAA for Hurricane Mitch shows computer generated rainfall data (Figure 7.2 on p. 75). The three-week precipitation from Mitch was about half the annual precipitation along the coasts, but as much as the annual precipitation in the centre of the region. The NOAA estimate for total rainfall from 25 October to 17 November suggests that in Honduras there are at least three main subareas with regard to the amount of rainfall associated with Hurricane Mitch. Torrential rains (>500 mm) were estimated for the northern and southern parts of the country, while high rainfall (300–500 mm) were recorded for the rest of the country, except for the extreme western part, which was affected by only moderate rainfall (150–300 mm).

Accordingly, within the Departments of Honduras, rainfall and runoff damage was characterized by three different levels of intensities (torrential, high, moderate), corresponding to decreasing amount of damage. Therefore, landslide damage could be considered included into the rainfall damage. Indeed, all other things being equal, as a first approximation, heavier rains will produce more landslides.

7.1.3 Flooding and sedimentation

The CINDI-USGS data on Honduras contains an ArcView shape file that shows satellite radar data. This radar image does not cover the whole country, so the flooded area is incomplete (see pink areas on map in Figure 6.1 on p. 71). In fact, a number of areas, but most notably the ones in the Gracias a Dios Department, had a much larger flooded area: a rapid comparison of the original radar data with the topographic data allows extension of the flooded areas identified by the radar satellite images to the areas that are more probably similar to the actual situation (see pink and red areas in Figure 6.1 on p. 71).

It is assumed that the damage produced by both flooding and sedimentation is maximum, and for most crops the damage would correspond to total destruction, although some types of tropical forest may survive flooding without major damage. Finally, sedimentation, particularly if mainly consisting of coarse pebbles, may reduce agronomic production potential in the following few years.

7.2 DEFINITION OF A CONVENIENT SCALE OF INTENSITY

The causes of damage described in the preceding section suggest a convenient way to build a simple preliminary scale of intensity (I_p) that can be applied to the Hurricane Mitch impact assessment (Table 7.1). This simple way to build a scale for hurricane intensity in agriculture cannot be extrapolated to other cases without a complete understanding of the specific local conditions. For instance, in the case of Mitch, wind was not a direct source of damage to agriculture, except along the northern coast of Honduras.

TABLE 7.1

Simple scale of rain-related intensity effects

I_p LEVEL	INTENSITY LEVEL
1	Areas affected by 'moderate rains'
2	Areas where 'high rains' occurred
3	Where the rainfall was 'torrential'
4	Flooded areas

CHAPTER 8

IMPACT EVALUATION AND CALCULATION

8.1 CALCULATION OF THE DISTRIBUTION OF DAMAGE

The distribution of the percentage loss could be evaluated by using either the direct survey of the intensity or the percentage loss in the field, or both (empirical analysis), or by using a KB to transfer the event intensity data in each parcel to the percentage loss of value for each component of the milieu (model analysis). For the specific case of Hurricane Mitch, a simplified preliminary approach was adopted, using the limited data available and a combination of both analyses (Table 8.1).

TABLE 8.1

Conceptual analysis in preparation for elaboration of percentage loss values

PARCELS	PARAMETERS CONSIDERED
AGUA	One assumes that these parcels make no substantial contribution to the impact assessment. The parcels with water are considered to be inactive, although they could be made active if it is realized that fishery makes, in fact, a measurable contribution to the total impact.
BOSQUE	These are relatively simple. It is a self-contained environment. The main activity in forestry is the production of timber. Access to the forest, machinery and marketing systems are the main requirements to support the activity.
CULTIVO, FRUTAL and PASTO	The components of the resource system for all three parcel types include: *Labour.* A reduction in worker numbers and knowledge, which may occur because of deaths or emigration, directly damages agricultural production in both labour capacity and know-how. *Villages and habitat.* The destruction of worker's homes affects agricultural production. Homes need to be reconstructed before "normal" life and work capacity returns to full power. *Land.* A number of causes may reduce the value of agricultural fields, such as erosion from runoff and sedimentation of pebble layers during flooding. The activity systems are represented by different agricultural production categories, including crops (annual and perennial) and animal husbandry activities. Supporting systems include whatever is needed to support and enhance agricultural production, such as buildings, tools, machinery, energy and input supply, access and marketing, and their related infrastructure.

A KB is not yet available that transfers the intensity of the hurricane in each parcel to the percentage loss of value for the various components of the milieu of each parcel. A disaster is usually, but not always, the result of a complex event. Clearly a hurricane – such as Mitch – is a complex event, because it generates damage through a number of primary and secondary events, with wind and rain leading to flooding, landslides, sedimentation, etc. In the table of disastrous events, the primary event (the cause of a disaster) and the consequent secondary events (triggered by the primary one) are identified.

Based on the preliminary scale of intensity specific to the Hurricane Mitch impact assessment and the four categories of parcels with their relative milieu components, a percentage loss was empirically defined for each component and the various parcels (Table 8.2).

TABLE 8.2

Loss estimate for components, related to event intensity

			RAINFALL INTENSITY			
	SYSTEM	**COMPONENT**	**Flood** **D ± E**	**Torrential** **D ± E**	**Heavy** **D ± E**	**Moderate** **D ± E**
Bosque	*Resource*					
	Activity	Timber extraction	10 ± 5	5 ± 3	1 ± 3	0 ± 1
	Support	Access	80 ± 10	50 ± 10	10 ± 5	2 ± 2
		Machinery	100 ± 10	20 ± 10	5 ± 5	0 ± 1
Cultivo*	*Resource*	Labour	10 ± 10	5 ± 1	1 ± 1	0 ± 1
Frutal**		Housing	100 ± 10	30 ± 10	5 ± 1	1 ± 1
Pasto***		Land *	50 ± 20	10 ± 5	5 ± 1	1 ± 1
		Land **/***	25 ± 10	5 ± 2		
	Activity	Crops*	100 ± 10	60 ± 20	30 ± 10	5 ± 2
		Perennial**	75 ± 10	35 ± 10	10 ± 10	
		Livestock***	35 ± 5	15 ± 1	0 ± 1	
	Support	Farm infrastructure	100 ± 10	30 ± 10	10 ± 5	0 ± 1
		Machinery and tools	75 ± 10	15 ± 10	5 ± 1	
		Water supply	50 ± 10	10 ± 5	2 ± 1	0 ± 1
		Fertilizers	30 ± 10	10 ± 5	2 ± 1	0 ± 1
		Access and markets	50 ± 10	30 ± 10	10 ± 5	1 ± 1
		R&D				

KEY: D = damage (expressed as %) ±E = error (expressed as %).

The definitions used in Table 8.2 take into account information about percentage losses from the FAO-WFP impact assessment report on Hurricane Mitch (FAO-WFP, 1999). Clearly, these values are oversimplified and are shown to illustrate the RADAR methodology, rather than reflecting the accuracy of the actual values used. A detailed field analysis by experts in both agriculture and natural disasters might improve the accuracy of the values used to valuate percentage losses.

In addition, the percentage loss is totally independent of the component value *per se* actually present in the field at the time of the disaster. To stress this fact, the percentage loss is generally treated independent of the value itself. The percentage loss, instead, is a direct function of the vulnerability of that value and of the immediate post-disaster recovery factor.

The estimated percentage loss should include a confidence interval (an estimate of the errors). In this way, error estimates could be carried along in the successive calculations of the impact assessment. An estimate of the percentage loss in activities for a flooding event in wood parcels might be 10 percent, with a 5 percent error approximation. Access roads to the forest, however, might be destroyed up to 80 ±10 percent, while machinery could be lost up to 100 percent. Of course, torrential, high and moderate rains would generate a percentage loss that is proportionally much less.

For *cultivo, frutal* and *pasto* parcels, the resource and support components of the milieu are damaged in a similar way, although annually cropped land is significantly more affected by erosion than perennial plots and permanent pastures. For the activity systems, a flood event could be 100 percent destructive for annual crops (depending on flood duration), while perennial crops might suffer 75 percent and pastures and livestock 35 percent loss, respectively, taking into account the actual physiological stage of components at the time of the event. Percentages of loss decrease significantly as the intensity of the event moves from being torrential to moderate rain. Moderate rainfall could generally be considered to have too little significant impact on activity system components.

The relative percentage loss values have been mapped (Figure 8.1 on p. 76), but bear in mind that any given percent loss of value is independent of the absolute value loss.

8.2 CALCULATION OF THE VALUE EXPOSED

One of the major difficulties during impact assessment is the evaluation of the value actually exposed to the disastrous event. Generally, no such data usually exist since it has to be frequently updated over each year (almost in real time).

Thus, the value actually exposed to the event needs to be extrapolated from data collected in preceding years, based on an intimate knowledge of the local farming systems, and errors associated with extrapolation should also be estimated.

8.2.1 Yearly production and areas harvested

The FAO-GIEWS database reports for each Department of Honduras, from 1990 to 1994, annual production and the areas harvested for major crops, including banana, dry beans, cassava, cocoa beans, green coffee beans, maize, onions, plantains, potatoes, paddy rice, soybean, sugar cane and leaf tobacco.

A number of attempts were made to extrapolate the 1990–1994 values four years ahead to 1998, but it was finally decided to use the 1990–94 average values for production and area harvested. The extrapolation of a four-year data sequence to four years ahead requires a use of more sophisticated methods of extrapolation that, in the end, may be statistically meaningless. However, in other cases, where longer time series of data are available, various kinds of regressions might be applicable. In addition, it is assumed that the error in the estimates is fairly well represented by the average deviation from the mean: the correlation coefficients between errors are also necessary to estimate the errors during the evaluation of the impact.

8.2.2 Crops

The first step in the calculation of the value for each component of the milieu is to convert the annual production (in tons) into its commercial value[24] (in local currency lempira or US dollars). The unit values in lempira for crops were derived from FAO-ESS tables[25], which report for each crop and for each Department the calculated annual production value.

To calculate the actual value at risk, the percentage of the crop that was actually present in the field or farm store at the time of the disaster was estimated. This percentage depends on the fraction of crops in the field at the time of the event and not yet harvested. For instance, for main crops, this fraction was estimated as shown in Table 8.3.

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[24] Average farm gate price (not necessarily market price).

[25] http://www.fao.org/es/ess/rmcrops.asp

TABLE 8.3

Estimates of annual production at risk at the time of Hurricane Mitch

CROP	FRACTION OF TOTAL ANNUAL PRODUCTION AT RISK
Bananas and plantains	Crops harvested throughout the year (life cycle of a bunch is 6–8 months). One can assume that one-half of the crop was already harvested when Hurricane Mitch hit, and that production would resume after 8–10 months from the event. Thus, the actual value at risk is about 70% of annual production.
Coffee	Harvest begins in October and usually continues through December. Thus, much of the ripe bean crop was still on the plants at the time of Hurricane Mitch: it is assumed that at least 90% of the annual crop production was actually at risk.
Maize	The first seasonal harvest (primera) was well underway and the second crop (postera), the larger part annual production, had recently been seeded. It was assumed that some of the first crop still remained in the field, the second crop was destroyed, but a third crop could still be seeded with higher yields than usual, because of the Mitch-associated rains. Hence, 70% of annual production was at risk.
Potato	This crop is mainly harvested at the end of winter. Thus, only 30% of the yearly crop was at risk in late October.
Rice	There are two main harvest periods during the year, of which the one in November is the largest. Thus, it was assumed that about 70% of the yearly crop was actually at risk at the end of October 1998.
Tobacco	A fragile crop, because the leaf value depends primarily on their quality. Since leaves may be damaged all through their life cycle, about 80% of the annual crop was at risk when Hurricane Mitch hit Honduras.
Sugar cane and cassava	Crops harvested usually during the dry season (January to May). Therefore the whole crop is still in the field in late October. Accordingly, for percentage of value at risk, a coefficient of 100% was used.
Other annual crops	While lacking specific information, it was assumed that 50% would be a reasonable estimate for the percentage of the yearly production value at risk.
Perennial crops	For perennial crops (coffee, cocoa, oil palm, etc.), potential production losses in subsequent years should also be taken into account.

NOTE: This example shows the application of RADAR to a real case. Thus, the accuracy of the coefficients of percentage of value at risk is of secondary importance. However, it is of primary importance that the actual values used be estimated as precisely as possible by experts in the field during impact assessment. In fact, RADAR might also be considered a very useful tool in support of field missions in disaster areas.

8.2.3 Forest

The value of forested land should be estimated by multiplying the number of hectares by the local price per hectare of forest. Such detailed information does not exist at sub-department level. Thus, the average commercial value of forest for the whole country and the number of hectares of forest in each department is used. The actual value at risk is finally obtained by multiplying the potential value by the percent of value at risk (100 percent).

Gracias a Dios and Olancho are the Departments with the largest extent of forested land and consequently probably the greatest forest value. In reality, distribution of value of forest may differ from that outlined here because of price variations that reflect location and forest type.

8.2.4 Pasture and livestock

The value of pastures is calculated on basis similar to that for forest land. In each Department, the area of pasture, obtained from the GIS map of land use, is multiplied by a country average price per hectare and by the percent of value at risk, to obtain the actual working value.[26] Since pastures in Honduras tend to remain productive throughout the year, the coefficient for percent of value at risk is taken as 100 percent. A 5 percent error has been assumed in the extent of pasture derived from the GIS model, with a minimum error of ±1000 ha.

The evaluation of livestock status is more complex. There are no data at Department level. Values for dairy and beef cattle are known only at national level. Thus, as an approximation, the number of animals was allocated countrywide on the basis of pasture area data available at Department level, which does not necessarily reflect the real distribution. The number of heads per Department was multiplied by the price per head of dairy or beef cattle, to obtain potential values for each category. The coefficient of percent of value at risk is 100 percent for both beef and dairy cattle.[27]

The value of the infrastructure is estimated at 10 percent of the value of the livestock, assuming that the cost of infrastructure for dairy cattle is twice that for beef cattle.

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[26] This valuation may overestimate the damage because pasture price is a function of ability of the pasture to produce grass over a number of years. Alternatively rental prices of pasture land for grazing may be used for estimating the monetary value of pastures in different parcels.

[27] More accurate valuation requires modeling herd structure (sex and age-group of animals) and related long-term effects.

8.2.5 Value density

The result of the estimated distribution of total agricultural value per hectare over Honduras at the time of Hurricane Mitch is illustrated in Figure 8.2. on p. 76.

It is immediately obvious that the greater part of the country, which is occupied by forest, has a relatively high value of between US$ 100 and 333/ha (although forested areas have quite low vulnerability and therefore smaller relative potential percentage loss for hurricane events).

The parcels with largest value density are the pastures with livestock, for instance, in Intibuca. In these parcels, in addition to the pasture and the animals, the costs of the infrastructure associated with dairy production have also been included. Unless flooded, these areas have comparatively low vulnerability and associated percentage loss.

Some cultivated areas, such as along the coast in the Department of Colon, have a relatively low value (US$ 33–99/ha). This is probably artificial, because the potential land use map assumes that potentially cultivated areas are in fact forested. Thus, the value of the crops on cultivated land parcels becomes artificially diluted over an area that is larger than the actual one. The same problem may be observed in the fruit tree (*frutal*) parcels of Choluteca, where the coffee plantations (*cafetales*) have the low nominal value of US$ 10–33/ha.

8.3 INTEGRATION OVER PARCEL COMPONENTS AND AREA

The evaluation of the impact of Hurricane Mitch in Honduras is obtained by evaluating and aggregating the loss of value (the damage or toll) of each component of the milieu in each parcel.

The evaluation of agricultural damage integrates the damage caused to the different components and includes the various calculated errors (an estimate of the accuracy of the calculated damage). The sum of the damage of all components of the milieu gives the damage for each parcel. In turn, the sum of the damage for all parcels provides the target overall evaluation of the damage (negative impact) of Hurricane Mitch in Honduras. This impact is evaluated at about US$ 750 million, with an estimated error of about ±8 percent (Table 8.4).

The estimated density distribution of damage assessed in unit-area monetary terms is illustrated in Figure 8.3 on p. 77. The highest density of damage (e.g. in Valle Department) is associated with pasture and fruit trees areas, where the unit density of value is highest. Of course, there are areas with similar value density, but with different density of damage. This is due mainly to different intensities of the event for the same land use. Less frequently, the same may happen due to the different vulnerabilities of various land use types for an equal intensity of event.

TABLE 8.4

Damage value due to Hurricane Mitch in Honduras, October 1998, for primary parcel components aggregated over all Departments. Values in US$,000s

DEPARTMENT	PRIMARY PARCEL COMPONENTS				TOTAL IMPACT
	Bosque US$ ± Error	Cultivo US$ ± Error	Frutal US$ ± Error	Pasto US$ ± Error	US$ ± Error
Atlantida	1 770 ± 922	6 150 ± 486	1 187 ± 1 187	2 872 ± 922	11 979 ± 1 841
Colon	2 982 ± 537	21 140 ± 1 481	276 ± 68	36 207 ± 7 348	60 605 ± 7 516
Comayagua	535 ± 1 605	7 391 ± 1 237	23 371 ± 7 946	1 358 ± 1 934	32 655 ± 8 426
Copan	52 ± 281	5 300 ± 1 032	24 605 ± 8 366	775 ± 352	30 733 ± 8 441
Cortes	713 ± 790	55 620 ± 3 311	10 259 ± 2 626	372 ± 532	66 965 ± 4 331
Choluteca	631 ± 357	9 214 ± 694	2 625 ± 648	388 ± 185	12 857 ± 1 032
Paraiso	2 411 ± 2 068	9 067 ± 1 239	33 462 ± 23 976	364 ± 180	45 305 ± 24 097
Francisco Morazan	2 306 ± 2 032	7 526 ± 1 146	7 861 ± 1 995	727 ± 634	18 420 ± 3 134
Gracias a Dios	8 361 ± 3 590	1 955 ± 148	62 ± 13	156 178 ± 38 450	166 556 ± 38 617
Intibuca	266 ± 799	4 182 ± 839	7 940 ± 1 125	2 634 ± 3 750	15 023 ± 4 083
Islas de Bahia	170 ± 103	87 ± 15			257 ± 161
La Paz	423 ± 549	1 628 ± 388	19 370 ± 19 370	4 210 ± 2 507	25 632 ± 19 543
Lempira	489 ± 1 466	4 021 ± 945	13 016 ± 4 426	1 948 ± 2 774	19 474 ± 5 507
Ocotepeque	37 ± 143	2 045 ± 309	10 289 ± 3 499	924 ± 1 201	13 296 ± 3 715
Olancho	6 469 ± 6 908	17 075 ± 2 062	20 656 ± 7 024	45 375 ± 11 037	89 574 ± 14 938
Santa Barbara	632 ± 1 895	10 201 ± 1 537	37 216 ± 12 654	439 ± 626	48 486 ± 12 902
Valle	174 ± 105	1 331 ± 309	24 ± 6	5 854 ± 1 898	7 383 ± 1 926
Yoro	3 991 ± 2 253	59 680 ± 6 373	21 834 ± 21 834		85 505 ± 22 857
TOTAL	32 411 ± 9 239	223 613 ± 8 277	234 054 ± 42 605	260 627 ± 41 148	750 705 ± 60 517

The map of percent value loss (Figure 8.1 on p. 76) combined with the intensity and impact density maps provides an additional tool for understanding impact distribution. The limitations underlined in Section 8.2.5 about the density of value apply also to the density of damage and percentage value loss maps. In spite of these limitations, the three map types that may be updated in real-time are clearly essential tools in defining the situation as intrinsic elements in strategic disaster recovery and monitoring programmes.

CHAPTER 9

CONCLUSIONS

An evolution from empirical towards a procedure-based model approach in disaster impact assessments is proposed in Part A for implementing a Rapid Agricultural Disaster Assessment Routine (RADAR). Once an extreme geophysical factor (an “event”) strikes a region, the user of the procedure should rapidly collect all available data on the event and the impacted region. A GIS-based Disaster Information Management System (DIMS) is then brought into play to assess the short- and long-term agricultural impacts of the event, based on a conceptual model that has been developed for the region.

The procedure uses a model analysis that is based on the physical simulation of the disastrous event, coupled with an empirical analysis that uses the people’s record of the environmental disruption after the event. Both analyses can be used alone, or concurrently; they can be updated in real time to improve the assessment. The output of the analyses is the area distribution of the intensity of the event, which is then used to assess the impact on (the damage to) agriculture as a result of the disaster.

This tool is very powerful for supporting decision-making during an impact assessment. Impact forecasting and updating are also possible, as ground and satellite data become available in the aftermath of the event.

Regarding the RADAR methodology, there is a need to:

- develop a proper typology of impacts as a first step towards the improvement of damage and risk assessment;
- define extreme events in terms of single directly impinging factors and their respective global and extreme magnitude and intensity;
- build a DIMS on a GIS platform, containing three separate but linked Impact Model (Model Base, MB), Knowledge Base (KB), and database (DB) of historical impacts providing a precise and quantitative description of historical impacts in the region and
- systematically collect pre-impact and post-impact descriptions of the areas affected by disasters together with detailed georeferenced information on the extreme factor itself (event). This database will provide the data that are necessary to derive the impact models.

Although impact assessment in support of relief and reconstruction operations appears as a primary objective for RADAR, accumulated information and in depth analysis would also provide, in the medium to long term, a significant contribution towards minimizing losses in disaster situations by, *inter alia*:

- better disaster preparedness and minimization of potential risks by improved early warning strategies and forecasts, evacuation planning and preparedness;
- adapted development planning for hazard-prone areas;
- better understanding of impact mechanisms.

In Part B, the RADAR methodology has been applied for evaluating the impact of Hurricane Mitch on Honduran agriculture, using the procedure described in Part A. The goal was to show its applicability to a real-world case.

Data from USGS-CINDI describing the physical event and providing general information on the administrative subdivisions in Honduras ("Departments") were combined with additional data on rainfall, derived from NOAA sources. Other data on crops affected originate from the FAO-WFP report on Hurricane Mitch. Because not all data needed for impact assessment were available, many extrapolations from older data sets (e.g. annual production and harvested areas), and even informed guesses, were used to quantify unknown parameters (e.g. the percentage loss for each crop category).

In applying RADAR, one of the first problems encountered was the dichotomy between data set distributions: the data for the physical event (Hurricane Mitch) and for the general eco-geography of Honduras is distributed evenly over the whole country; the data on agricultural production is grouped by Department. Therefore, both data sets need to be "homogenized" by distributing the agricultural production components over parcels (within Departments). In turn, because the map of potential land use is not the actual land use (which is unknown), the distribution of crop production systems was approximated by relative proportions of harvested areas.

After generating a GIS model of the area affected, four levels of intensity of the event were determined. The final model has a set of 123 parcels: each parcel belongs to the same Department, has the same kind of agricultural production and the same event intensity. Based on the definition of the components of the milieu, their respective percentage of damage in each parcel and their value before the event, the total damage (negative impact) of Hurricane Mitch on Honduran agriculture can be approximated. The final estimate of the impact is about US$ 750 million, with an 8 percent error in the estimate. Despite the limitations with regard to available information, RADAR is fully implemented in this example and shows its practicality and potential for application to real world impact assessments. The value of damage generated by the RADAR approach is acceptably close to that obtained by the FAO-WFP direct impact evaluation mission.

One of the major advantages of RADAR, relative to common practices in impact assessment, is that it provides, in addition to the impact, an estimate of the overall error implicit in the assessment. In spite of the fact that the errors in evaluating single components of the milieu may be large, by integrating the losses over the whole area of analysis, the final assessment remains statistically robust, with a relatively small error.

One other advantage is that RADAR provides the area distributions of event intensity, percentage loss of values and damage density over the impacted area. These distributions are, indeed, essential tools in defining strategic disaster recovery and monitoring programs.

Finally, another advantage is that RADAR can be easily implemented using simple off-the-shelf software tools, such as any vector-based GIS in combination with relational database software. Obviously, a full implementation of RADAR should use GIS extensively and exploit the great potential of relational database tools. This approach would bring the conceptual model of the affected area to its full application potential during rapid impact assessment and real-time monitoring of impact evolution.

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APPENDIX 1

QUANTITATIVE DEFINITIONS

<table>
<tr><th>Eq. No.</th><th>NAME</th><th>SYMBOL</th><th>FORMULA</th></tr>
<tr><td>1</td><td>Area</td><td>A</td><td>$A = \int_A da$</td></tr>
<tr><td colspan="4">Part of a region where the evaluation of the impact of a disaster is to be conducted. Conveniently subdivided into parcels (a) that may be considered as having constant property values for the components of interest.</td></tr>
<tr><td>2</td><td>Surface of the area</td><td>S_A</td><td>$S_A = \int_A s_a da$</td></tr>
<tr><td colspan="4">To obtain the actual surface of the area (S_A), each parcel must be multiplied by the surface of the parcel (s_a). Units: hectares (ha) or square kilometres (km^2).</td></tr>
<tr><td>3</td><td>Milieu of a parcel</td><td>C_A</td><td>$C_A = \int_A \int_{C_a} dc_a da$</td></tr>
<tr><td colspan="4">Milieu of an area (C_A) includes all natural and socio-economic (human) components that are of interest for the impact assessment in the area. Component (c_a) is a part of the milieu of a parcel, which can be delimited and considered as distinct from the rest; the sum of all components over all parcels forms the milieu of the area (C_A).</td></tr>
<tr><td>4</td><td>Damage to a component</td><td>D_{c_a}</td><td>$D_{c_a} = V_{c_a} \cdot L_{c_a}$</td></tr>
<tr><td colspan="4">The value loss for the component when “recording” an *event* is given by the product of the *value* (V_{c_a}) and the *percentage loss* (L_{c_a}) for that component.</td></tr>
<tr><td>5</td><td>Recovery factor</td><td>$F^n_{c_a}$</td><td></td></tr>
<tr><td colspan="4">The recovery factor is the % of the damage mitigation $(F^n_{c_a} > 1)$ or increase $(F^n_{c_a} < 1)$ in the lag time between two subsequent events.</td></tr>
</table>

Eq. No.	NAME	SYMBOL	FORMULA
6	Damage to a component after N events	$D_{c_a}^{N}$	$D_{c_a}^{N} = V_{c_a} \cdot \prod_{n=1\rightarrow(N-1)} \left[F_{c_a}^{n-1} \cdot \left(1-L_{c_a}^{n}\right)\right] \cdot L_{c_a}^{N}$

The damage (loss of value) of a component after N contiguous disastrous events. The loss of the actual value after each disaster event multiplied by a recovery factor ($F_{c_a}^{n}$).

7	Damage in the parcel	D_a	$D_a = \int_{C_a} D_{C_a} dc_a = \int_{C_a} \left(V_{C_a} \cdot L_{C_a}\right) dc_a$

The sum of the damage of all components of the *milieu* of a *parcel*.

8	Damage to the area by an event	D_E	$D_E = \int_A \int_{C_a} \left(V_{C_a} \cdot L_{C_a}\right) dc_a da$

The damage to the area due to an event (subscript E) is given by the integral of the value multiplied by its percentage loss over all parcels over all components of the milieu of each parcel. The damage of the area corresponds to the *toll*, that is the negative *impact*, produced by the event in that area.

9	Magnitude of an event and local magnitude of an event	M_E M_{la}	$M_E \leq \int_A M_{la} da$

The local magnitude (M_{la}) of an event measures the energy of the event that is locally associated with the event. It is a function of the local duration and amplitude of the event. Note that the integral over the area of the local magnitude is usually more than the magnitude of the event (M_E).

10	Intensity of an event	i_{c_a}	

Empirical quantitative measure of the degradation produced by the event in any given parcel. The component intensity (i_{c_a}) is defined in general for each component of the milieu of a parcel (subscript c) for each parcel (subscript a).

Eq. No.	NAME	SYMBOL	FORMULA
11	Intensity of the event in a parcel	I_a	$I_a = \frac{1}{C_a} \int_{C_a} w_{c_a} i_{c_a} dc_a$

The weighted average of the component intensities for that parcel, where w_{c_a} is the component weight of any given parcel.

12	Magnitude-Intensity relation	$\Phi_{M \to I}$	

The local magnitude (M_{la}) is related to the intensity of an event in a parcel (I_a) by transfer function ($\Phi_{M \to I}$) that is based on past experience (when both quantities are known in each parcel), by calibrated modelling or by more empirical functions that relate local event energy to parcel milieu degradation.

13	Intensity of an event and percentage loss	$\Psi_{I \to L}$	

The intensity of an event is related to the percentage loss for each component (L_{c_a}) by empirical transfer functions ($\Psi_{I \to L}$) that are based on past experience (or modelling). I_η is a dummy variable that can take the value of either I_a (the intensity of the parcel) or i_{c_a} (the intensity of each component of the parcel) depending on how the value of intensity is obtained. Note that the percentage loss must be obtained for each component of each parcel (subscript c_a). Thus, if one directly measures the component intensity i_{c_a} (for instance, by visiting the disaster area), then the percentage loss for each component L_{c_a} is going to be computed with high accuracy. In contrast, if one obtains the intensity of the parcel I_a from the local magnitude of the event M_{la} (Eq. 12), the percentage loss for each component is going to be computed less accurately, because I_a is used in Eq. 13 as a surrogate for the actual i_{c_a}.

14	Hazard	H_{EM}	$H_{EM} = \prod_{j=n-0} \chi H_{Ej}$ where χ is a correlation function between the events that is equal to 1 if there is no correlation.

The potential or probability of occurrence of an event (E), of a given magnitude (M), in a defined region and time interval, is called the hazard of the event. Frequently, an event may trigger another event or a chain (actually a tree) of indirect events. The relation between the hazard of direct and indirect events may be described by a probability tree θ_{E}, in which the "trunk" element (order 0)

Eq. No.	NAME	SYMBOL	FORMULA

contains the probability of occurrence of the direct event (that is, its hazard). The first set of “branch” elements contains the probability of occurrence of the first set of indirect events (order 1), that are triggered by the direct event. The second set of “branch” elements contains the probability of occurrence of the second set of indirect events (order 2) that are triggered by the first set of indirect events, and so forth. Thus, the hazard of an indirect event of order n (E_n) along the “branch” chain is given by the product of all elements along the same branch chain going backwards from E_n to the direct event included.

15	Vulnerability	W_{c_a}	

The vulnerability W_{c_a} of a component of a parcel is defined as the potential percentage loss of value of each component of the milieu of a parcel, for an event of given type and magnitude. Once an event has occurred, the vulnerability is substituted by the actual percentage loss of value (L_{c_a}).

16	Risk	R_{EM}	$R_{EM} = H_{EM} \int_A \int_{C_a} \left(V_{c_a} \cdot W_{c_a}\right) dc_a da$

The risk (R_{EM}) is a measure of the prospective damage of a potential event (E) of magnitude (M) in a given area and time interval. It is the integral over all components of each parcel in the area of the potential loss and has the same units as the value. Once the event happens, the hazard becomes 1 and the potential percentage loss (W_{c_a}) is replaced by the actual percentage loss (L_{c_a}). Thus, Eq. 16 reduces to Eq. 8.

17	Errors	$\sigma_{xi}\ \ \sigma_{xj}$	$y = f(x) = f(x_1, x_2, x_3, ..., x_N)$ $\sigma_y = \left[\sum_i \sum_j r_{\sigma_{x_i}\sigma_{x_j}} \sigma_{x_i} \sigma_{x_j} \left(\frac{df(x)}{dx_i}\right)\left(\frac{df(x)}{dx_j}\right)\right]^{\frac{1}{2}}$

A set of parameters x_i is affected by errors σ_{xi}.
The quantity y has an error σ_y that is obtained by error propagation of the x_i.
$r_{\sigma_{xi}\,\sigma_{xj}}$ is the correlation coefficient between the errors σ_{xi} and σ_{xj}

APPENDIX 2

FIGURES AND MAPS

FIGURE 6.1

Chart of the progress of Hurricane Mitch and flooded areas

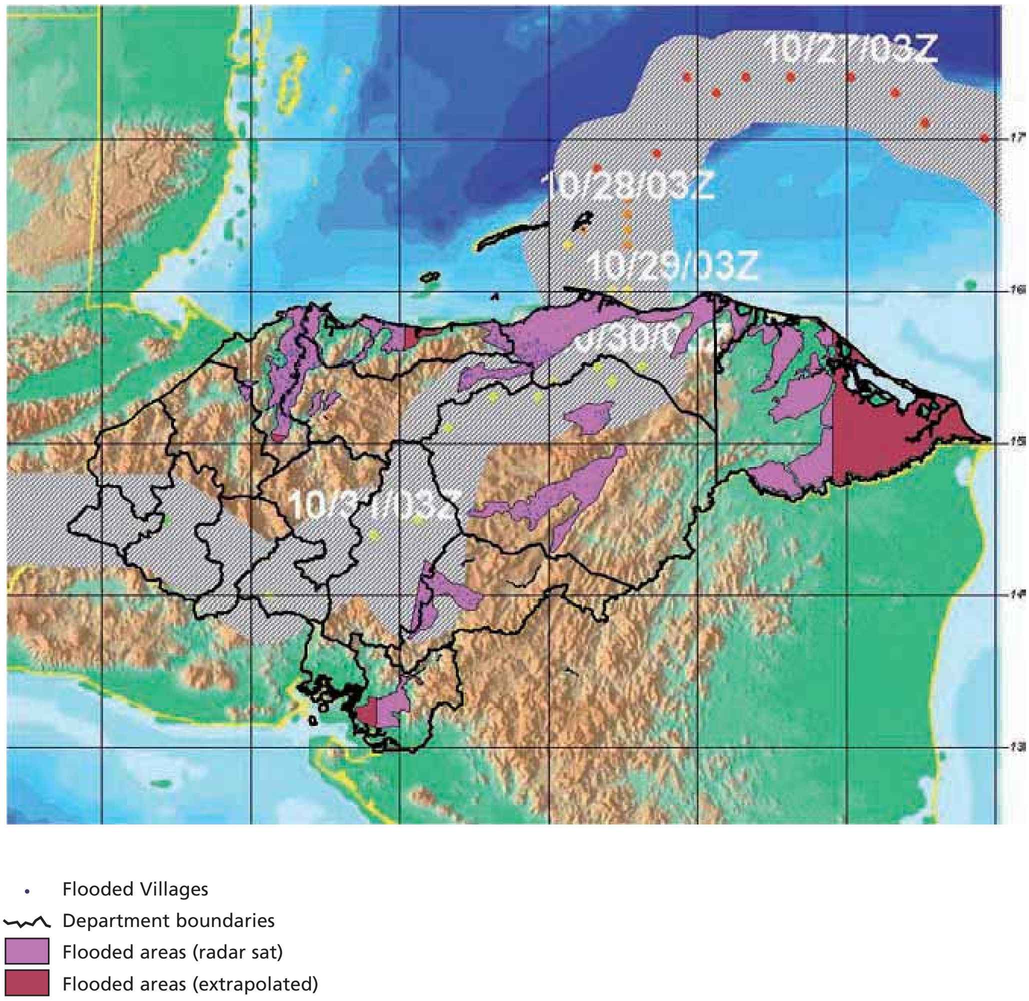


FIGURE 6.2

Simplified categories for land use in Honduras

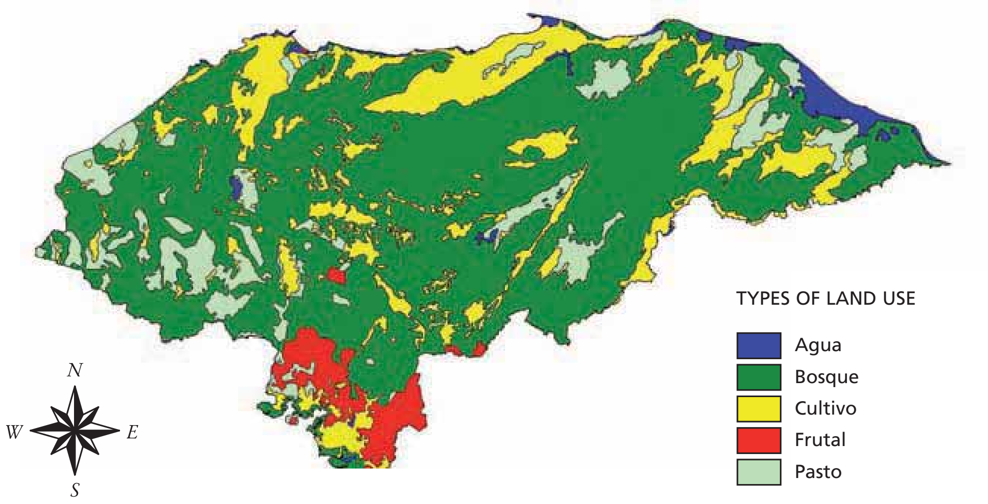


FIGURE 6.3

Parcels for impact assessment

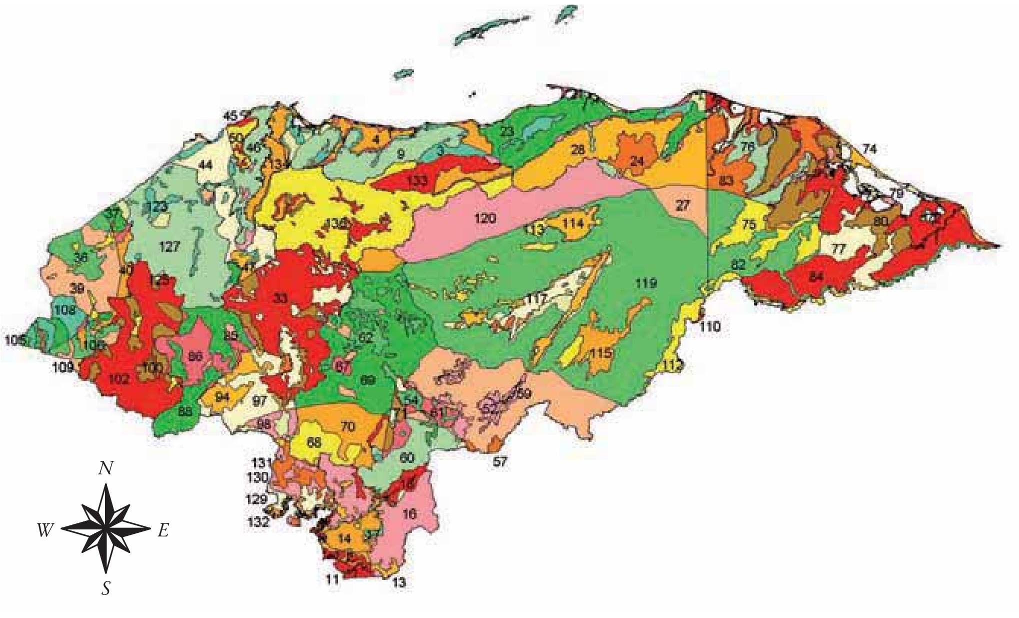


FIGURE 6.4

Starting window for assembling elements for the conceptual model

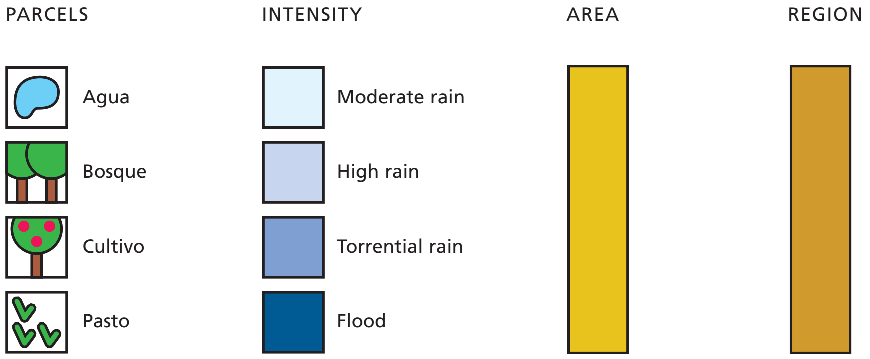


FIGURE 6.5

Building up parcel definitions by selecting elements for each Department

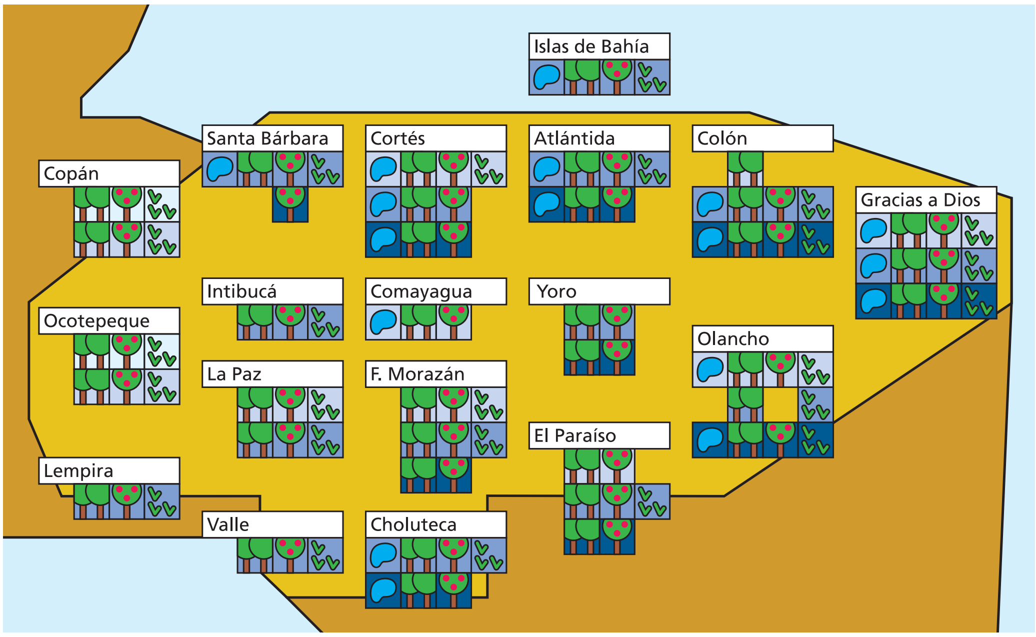


FIGURE 7.1

Average annual rainfall for Honduras (from CINDI/USGS)

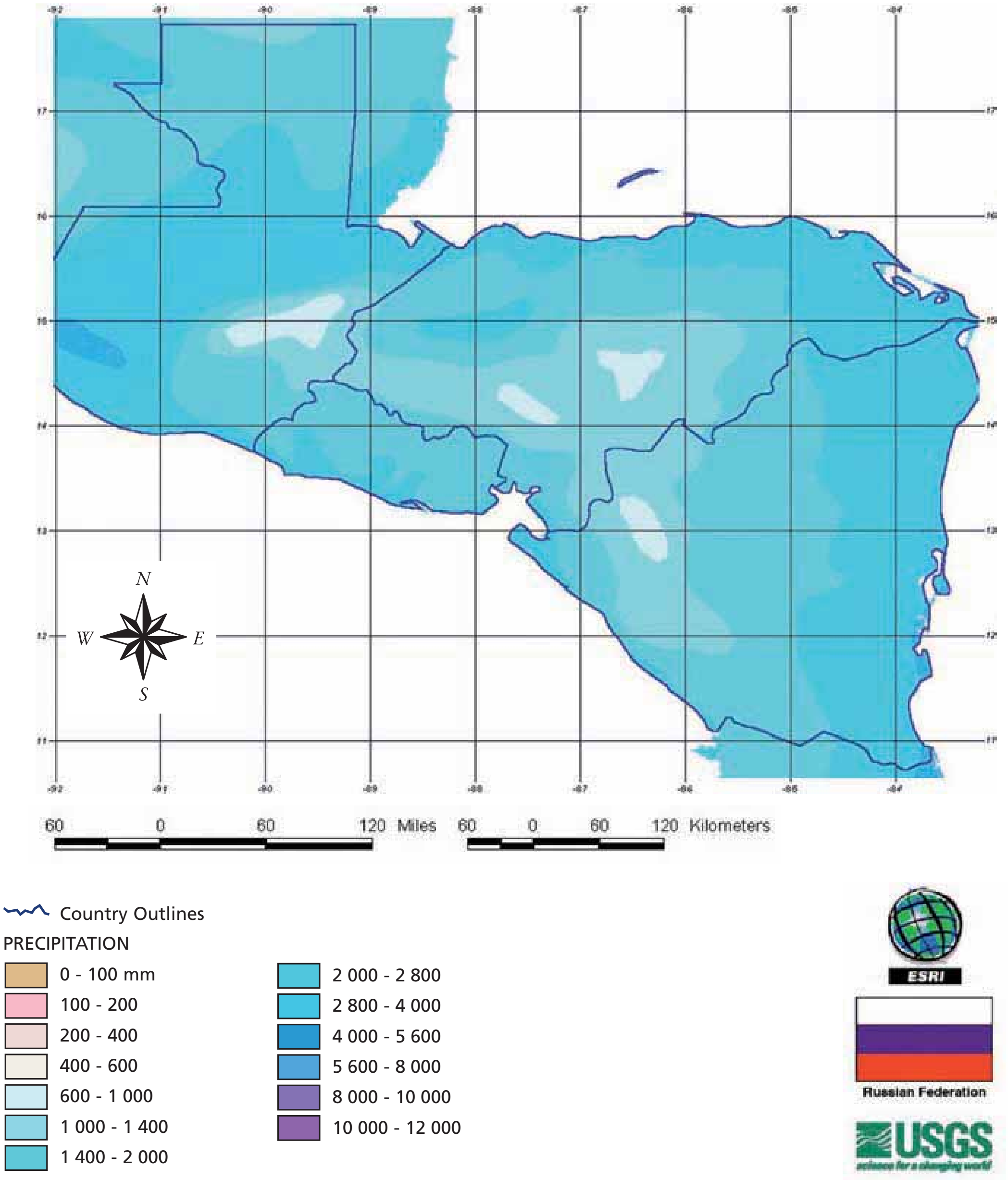


FIGURE 7.2

Rainfall associated with Hurrican Mitch (from NOAA/EarthSat)

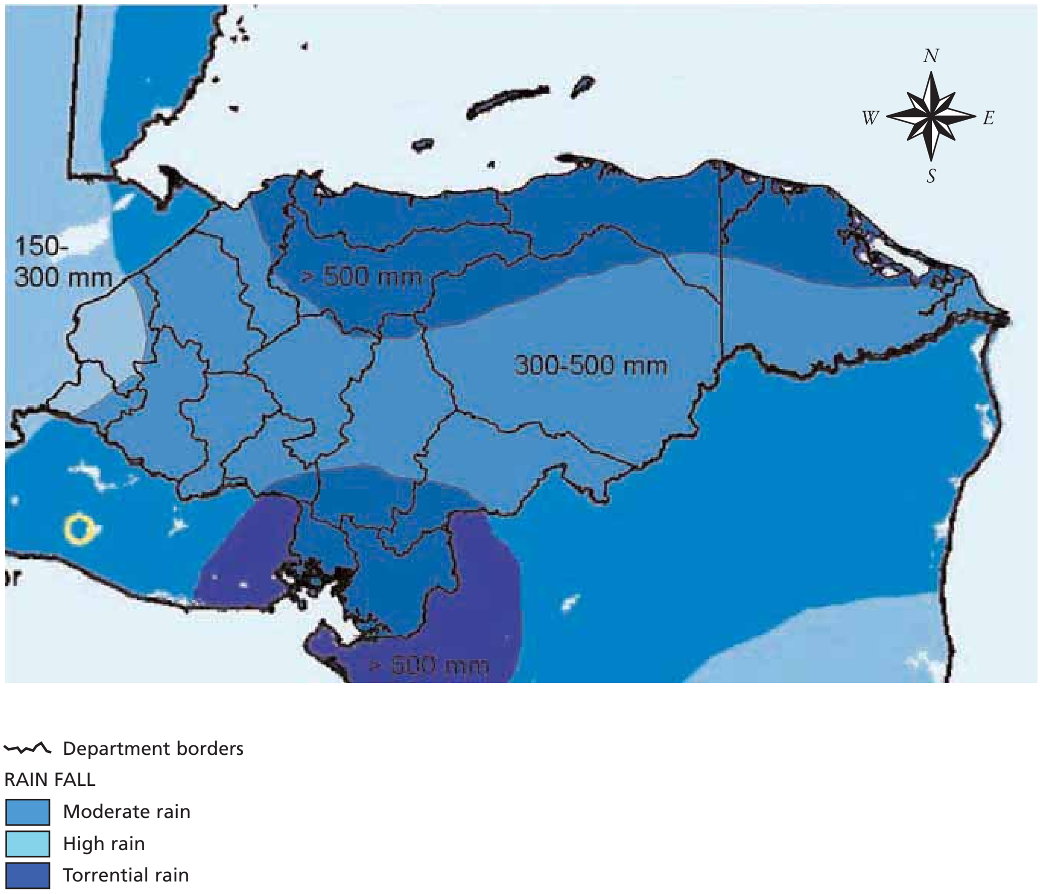


FIGURE 8.1

Percentage loss values following Hurricane Mitch, Honduras, October 1998

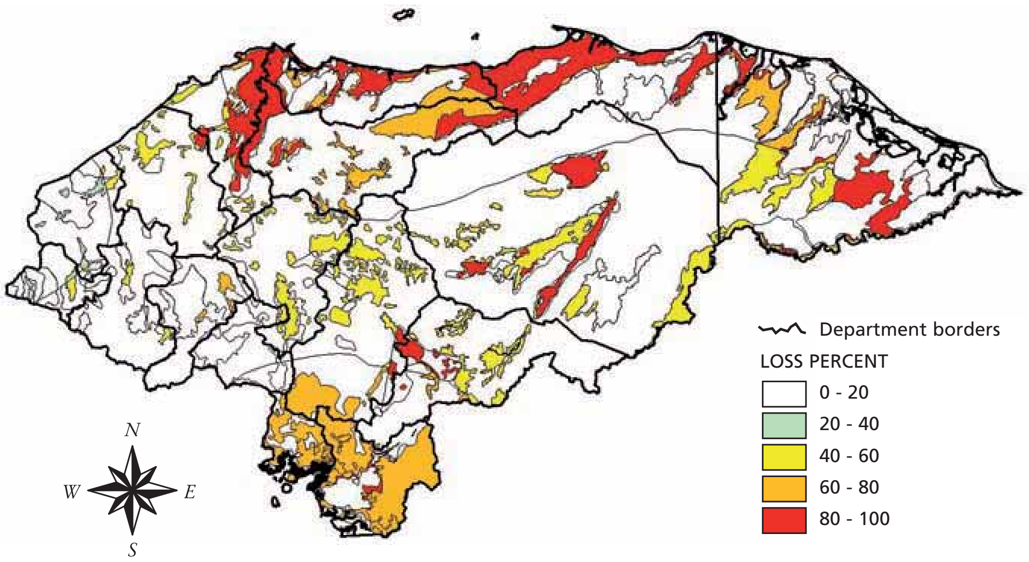


FIGURE 8.2

Estimated distribution of value density across Honduras at the time of Hurricane Mitch

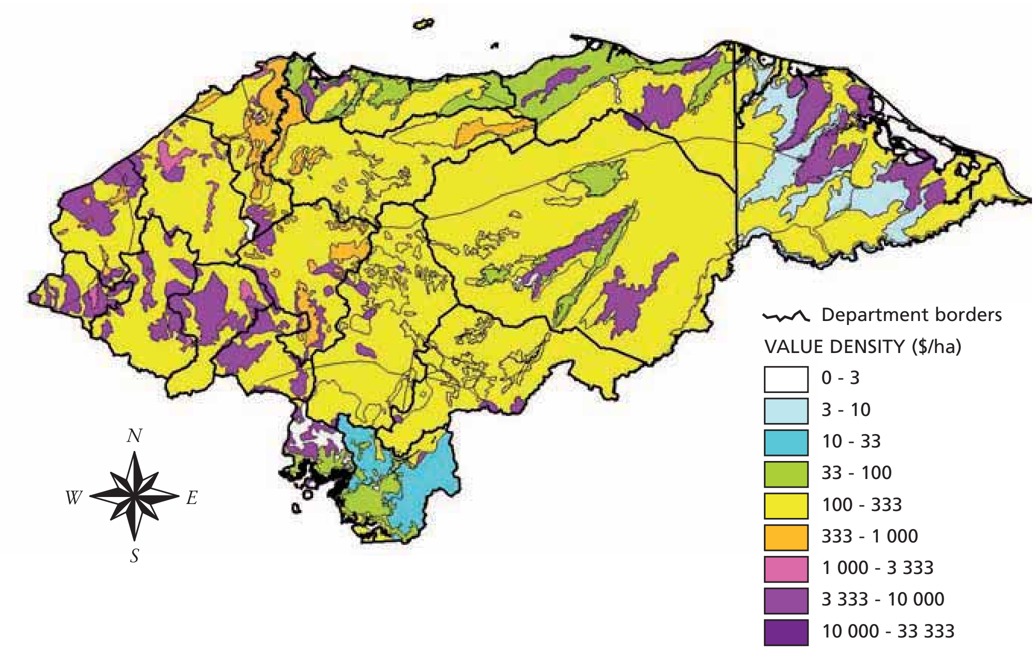
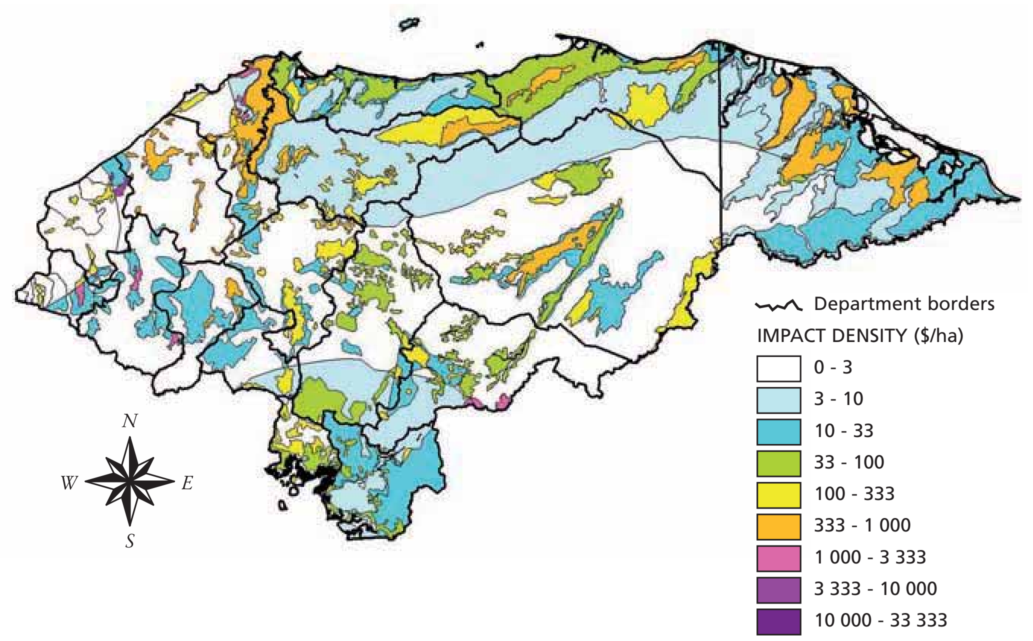


FIGURE 8.3

Distribution of damage impact in monetary terms per unit area (US$/ha) in the aftermath of Hurricane Mitch in Honduras, October 1998



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The Rapid Agricultural Disaster Assessment Routine (RADAR) is based on the idea that a disaster is the "product" of extreme factors and a vulnerable agricultural system. This book proposes to move from empirical assessments of disaster impact on agriculture towards model-based approaches. Once an event strikes a region, the user of the procedure should rapidly collect all available geo-referenced and quantitative data on the event and the region. Subsequently, a Disaster Information Management System that integrates physical models, knowledge-bases, databases and GIS can be used to assess the short- and long-term agricultural impact of the event. The output of the analyses is the geographical distribution of the intensity of the event, which is then used to compute the integrated impact on agriculture produced by the disaster. In the medium- to long-term accumulated information and in-depth analysis should provide a significant contribution towards disaster preparedness and minimization of potential risks through early warning strategies and preparation of development plans that incorporate resilience to such disasters.

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