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.

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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