

MANAGEMENT AND PREVENTION OF NATURAL DISASTERS - WHAT ARE THE REQUIREMENTS FOR THE EFFECTIVE APPLICATION OF REMOTE SENSING?

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ABSTRACT:

Immediately after the flood events in Mozambique, the debate about required measures to be undertaken focussed on issues such as rescue and relief operations. The analysis of the whole process of disaster management and prevention yields 4 main aspects which can be characterised by time, complexity and scale. Forecast leading to early warning (1) precedes the event, triggered by the event assessments of flood extent and damages inflicted guide emergency operations such as rescue and relief (2). Post-crisis activities include rehabilitation (3) measures in the short term and prevention (4) in the long term to improve early warning and reduce the impact of future flood hazards. An account of the *lessons learnt* demonstrate that a frequent bottleneck exists between data providers and users: if data are not requested, the means to derive information from these data do not exist and the dissemination of this information does not happen efficiently even the best technology cannot have an impact. Data from satellite sensors play an important role in disaster management and crisis prevention. Their effective application depends not solely on technical specifications, but is influenced by factors such as data distribution, capacity building, institutional development and information sharing.

1. FLOODS IN MOZAMBIQUE

The history of Mozambique shows repeated occurrences of various forms of natural disasters such as floods, drought and cyclones. The country's weak economic infrastructure and the general prevailing state of poverty are aggravated by the frequent occurrences of disasters making it difficult to undertake development activities.

The recent floods and their aftermath accentuated the need for a well-defined plan of action in the strengthening of the country's response capacity and its commitment for preparedness and prevention/mitigation of future calamities. The extent of human suffering and the economic impact of the February/March 2000 floods have been significant. The population of the affected areas constitutes 27% of the overall population of the country (4.5 million people). Approximately 544.000 people have been displaced and at least 699 persons were killed. About 2 million people lost property of some kind ranging from houses, stores, means of transport, animals, and cultivated land.

However, Mozambique's own experience in dealing with complex emergencies during its history of civil strife and encounters with natural disasters has provided it with a degree of experience in establishing an institutional base for disaster response. With a substantial change in the philosophy of dealing with disasters and the need for an integrated long term plan of not only responding to disasters but also preparedness and mitigation, a new organisation was born in June 1999 with a mandate of coordinating all disaster related activities. According to the National Policy on Disaster Management the objective of the National Institute of Disaster Management (INGC, Instituto Nacional de Gestão das Calamidades) is disaster management and the coordination of prevention activities, relief to disaster victims and the rehabilitation of affected infrastructure.

The role of a national coordination entity requires the ability to call on and galvanise all available resources in case of emergency and the organisation of a response capacity during the time of normalcy. Apart from the legislative authority that allows it to mobilise national resources, the Institute must also have the human resource and material base to undertake the coordinating task. The transformation from an operational entity to a coordinating body has not been concluded. Therefore, the national capacity to prepare and respond to a national disaster is in a very weak state particularly immediately after the devastating impact of the floods that occurred in February and March of 2000 and 2001 (INGC/UNDP, 2001b).

2. INFORMATION NEEDS AND EO SERVICES

Immediately after the flood events in 2000, the debate about required measures to be undertaken concentrated around issues such as rescue and relief operations. Under the fresh impression of the disaster the question of how lives can be saved and those who have escaped can be supplied efficiently with food, drinking water, shelter and medical care are certainly most pressing. The analysis of the whole process of disaster management and prevention – here carried out for the particular case of floods in Mozambique - yields however 4 main aspects which can be characterised by time, complexity and scale. In relation to a certain flood event forecast leading to early warning precedes (1) the event, triggered by the event assessments of flood extent and damages inflicted guide emergency operations such as rescue and relief (2). Post-crisis activities include rehabilitation (3) measures in the short term and prevention (4) in the long term to improve early warning and reduce the impact of flood hazards.

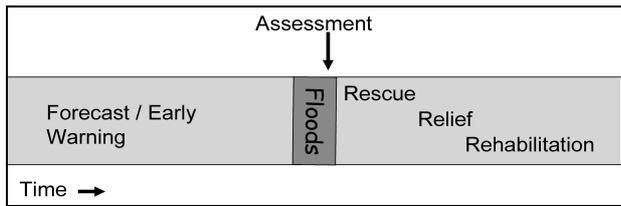


Figure 1. Aspects of flood disasters (time line)

Each of the activities to be carried out under these aspects requires specific data to be processed into requested information. In order to assess the application of remote sensing data we will look at the tasks in more detail.

2.1 Early Warning

The main activities include continuous monitoring, assessment of anomalous situations and the effective and timely dissemination of information. As floods are not isolated phenomena, the linkage to regional and international observation networks are essential. Meteorological data on seasonal and short term weather conditions, specific events such as cyclones and tropical rains have to be combined with hydrological data (dam levels, river gauges) from within the country as well as from neighbouring regions. The warning production comprising data processing and analysis as well as evaluation can be improved by real-time weather satellite transmissions (e.g. METEOSAT) and rainfall estimates derived from NOAA data as produced by regional centers on a regular basis. The warning information is preferably disseminated in graphical form (flood forecasting maps) to enable the recipient to interpret and use it properly in the own context (Panel of experts, 2000).



Figure 2. Main components of disaster management

2.2 Emergency Operations

Planning, management and communication are the core activities under an emergency. The effective performance in these tasks is highly dependant on the reception of accurate, concise and timely information as well as the dissemination of information with the same quality standards. Prime data are here the assessment of flood extent and the damage inflicted on communities and the infrastructure to reach them. Based on the assessment’s evaluation, operational plans are been drawn up to mobilize existing resources and establish requests for additional support. Once the dimension is known rescue and relief operationals need information on locations, land cover and accessibility. Furthermore data on health hazards, availability of drinking water resources and food supplies are essential for planning relief measures.

Flood extent has been successfully mapped by using RADAR satellite data if suitable reference scenes were available. Information extracted from optical imagery (e.g. LANDSAT ETM) is used to update land cover databases and allow to analyse changes between dry season and post-flood conditions (if cloud covers permit). The assessment of agricultural areas by comparing pre-flood and post-flood imagery may be mentioned as one example.

2.3 Rehabilitation

Once the crisis has passed, reconstruction, resettlement and rehabilitation follows. What is needed are damage assessments and impact analysis to direct development planning as well as monitoring and evaluation of the measures undertaken.

If we look at food production, the first step is the analysis of damaged agricultural production areas by overlaying information layers showing flood extent and land use data derived from space data. The results enable us to prioritise seed distribution and the delivery of tools to farmers. Later in the season remote sensing assisted pre-harvest crop estimates assess the effectiveness of these measures and help to anticipate food shortages.

2.4 Prevention

Floods are not avoidable but the damage they inflict can be minimized through the provision of appropriate and timely information (Panel of experts, 2000). That information is put to use requires the awareness about the context (catchment) and the recipient’s capacity to apply it for decisions. Hazard zoning based on hydrological models for catchment areas outline locations for the resettlement of communities to safe areas or at least indicate positions for shelters where materials for emergency situations are stored. In the long term, the assessed hazard pattern should influence resettlement schemes and initiate the development of policy options.

In addition to the already listed information products derived from EO data (e.g. land cover and land use assessments), catchment information systems for flood modelling need to include detailed elevation data. Hazard mapping, allocation of safe areas is all directly associated with terrain height. Digital terrain models can be established from RADAR interferometry at accuracy appropriate for the large catchments of Mozambique.

2.5 Disaster Classification

A fifth topic could be added to the action list; one can regard disaster classification as pre-condition for the previous aspects. Only if we have a commonly accepted definition of disasters (floods, drought, cyclones) comprising their nature, time scale and impact, we can establish indicators by which they are detectable. Based on the set of indicators suitable observation systems are designed, made operational and be continuously improved to supply information on anomalies which indicate approaching floods - the task of early warning.

3. LESSONS

After the flood events in 2000 and 2001 several assessments took place at different levels, political, scientific and technical (INGC/UNDP, 2001a; Panel of experts, 2000). The results and

recommendations have partly been incorporated into project plans (UNDP, 2000; INRC, 2001) and to a lesser degree appear as objectives in operational plans of programs in progress (FEWSNET, 2001; CDG, 2001; DLR, 2001).

The performance of information provision from EO data to actors involved in the process of disaster management will be outlined for the specific tasks.

3.1 Early Warning

Weather observation by geostationary satellites can be regarded as one of the few spaceborne applications which are fully operational. Specifically if the existing data provision in (near) real-time is considered. Even though accessible on the internet, satellite-based assessments for storms and tropical rainfall are little known outside of meteorology experts' circles.

3.2 Emergency Operations

In 2000, flood extent analysis maps processed from RADARSAT data recorded on Feb. 23 appeared a week after the event on the web (www.dartmouth.edu/~floods/), but only for the southern part of Mozambique (Limpopo/Inkomati confluence just north of Maputo). During the following days these data were known to experts with access to internet (mainly outside of Mozambique) and turned out to be a most valuable set of information when disseminated through the UNDP information system (www.unsystemmoz.org). For other areas of the country similar information was not produced at the time either due to missing data or lack of requests. Countrywide flood extent was instead assessed by visual inspection (survey flights) or estimated from spot observations. Information on flooding in some remote areas of the eastern part of Mozambique was received 4 weeks after the main event occurred. The recording times for different systems reveal the severe restrictions for satellite based flood mapping.

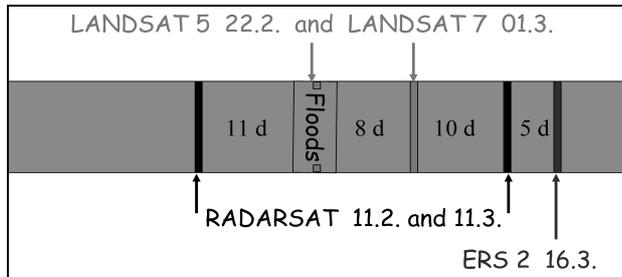


Figure 3. Satellite data availability for Central Mozambique (February and March 2000); d = days

During the floods of 2001 the national remote sensing center (CENACARTA) was not approached with request for information derived from satellite data even though the institution offered services to organisations involved in emergency operations. Meanwhile data for certain regions of the country were ordered by individual projects to cover specific areas of interest. A national data infrastructure to share information and to enable a coordinated data request has still to be developed. Two centers in the country have the capacity to process satellite data and to disseminate information products such as image maps. However, the expertise to use RADAR data for flood extent assessments is lacking and disaster management organisations still depend on products originating from institutions abroad.



Figure 4. Save delta, Central Mozambique, ERS-2 data (March 16, 2000)

3.3 Rehabilitation

Most of the programs were planned and implemented on the basis of data hastily compiled from different departments. Presentation of results from studies such as FLAME (see Steinbruch et al., 2002) at expert meetings revealed that essential information for example food or seed distribution is still not available for most areas. FAO and WFP were extremely interested in a regional assessment of inundated agricultural land (cross examination of a water mask derived from LANDSAT ETM and digital land cover data containing land use classified by intensity of utilisation) to improve estimates for the amount and nature of food and seed drops and their correct placement. Several reports on 'lessons learned' (UNDP, 2001) state that impact assessments of passed flood events are urgently required to build a consistent baseline data set for the improved management of future flood events. Particularly needed is a contiguous DTM database for the whole country or at least for the areas of the main catchments. Working groups are still dependant on specially compiled data sets digitised from analogue maps. Selecting locations for emergency shelters or the allocation of resettlement areas are crucially depending on accurate height data at a resolution of at least 25 x 25 meters. Similar requirements refer to the activities listed for prevention objectives (hydrological modelling, hazard zoning, land use planning).

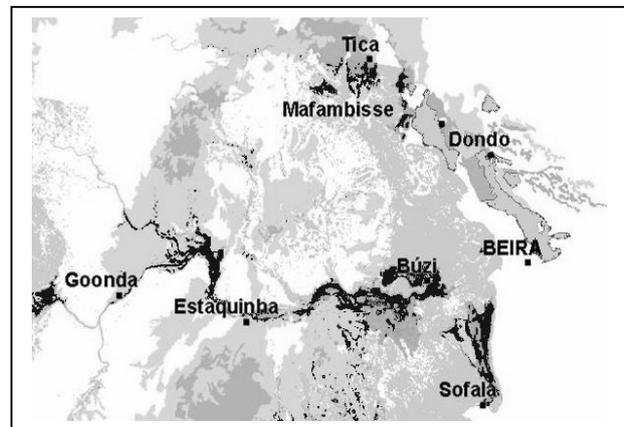


Figure 5. Flooded agricultural land (black) and land use (grey values) (Gall, 2001)

4. TASKS AHEAD

What can be extracted from the accounts of the Mozambique floods in respect to tasks ahead for improving the operational application of remote sensing? Certainly one can think about better technical specifications. But as the lessons learnt demonstrate, a frequent bottleneck exists between data providers and users: if data are not requested, the means to derive information from these data do not exist and the dissemination of this information does not happen efficiently even the best technology cannot have an impact. In an attempt to present answers to the title question: 'What are the requirements for the effective application of remote sensing?' we have to consider several aspects.

4.1 Technical Aspects

There is some hope to improve the timely coverage by using the experimental sensor MODIS. The instrument is capable of showing land cover dynamics on a global scale, every day (10:30 and 13:30 equatorial crossing), at up to 250 m resolution. Another copy of MODIS will fly aboard the platform Aqua, in spring 2002, with an afternoon equatorial crossing. How far the data can be used for flood mapping is explored by two teams (DLR, 2001; JRC, 2002). Successfully placed into orbit on March the European satellite ENVISAT will provide a new source of RADAR data for flood assessments if the huge number of projects proposed by prime investigators yield positive results. The satellite may also contribute to the production of Digital Terrain Models by using interferometry. Data release from the SRTM shuttle mission is still pending. To facilitate the planning process for disaster relief operations and to enable timely data requests, a web-based catalogue for expected data takes would be helpful. For a specific location and day the listings should render information such as which sensor would overpass at what time, what the footprint will be and what percentage of cloud cover could be expected.

4.2 Data Distribution

In crisis situations data should be readily available, also for those nations which do not have or cannot afford their own space programs. Since November 2000 the 'Charter On Cooperation To Achieve The Coordinated Use Of Space Facilities In The Event Of Natural Or Technological Disasters' (www.disasterscharter.org) has been launched by several space agencies. It is hoped that more agencies will join the charter and its content be made known to all concerned. To receive the full benefit of eased data distribution, countries – and in particular those frequently affected by natural disasters – have to develop and maintain centers which are capable to process satellite remote sensing data and to deliver information products.

4.3 Capacity Building

Information for disaster management can only be produced reliably and timely by local institutions. Databases on land cover, land use, socio-economic indicators have to be updated regularly and require local knowledge. National centers for remote sensing and geoinformation need the strong support by governments. The staff requires continuous training and scientific exchange to improve information provision and apply new methodologies. In many cases the assistance by the international community is required to realise the establishment of these centers.

4.4 Information Dissemination

Decisions have to be made swiftly when dealing with emergencies. In this case, information has to reach the actors in time and in a format they expect and understand. Therefore commonly known information channels have to be arranged and responsibilities be clarified. Even though these aspects refer to the organisation of national emergency plans, the point is made here in regard to the required standards in which satellite information products should be delivered in order to be accepted. Recipients need to be aware of the potential and limitation of the product and providers have to understand the information needs of their clients.

5. CONCLUSIONS

Data from satellite sensors play an important role in disaster management and crisis prevention. Their effective application depends not solely on technical specifications, but is influenced by factors such as data distribution, capacity building, institutional development and information sharing. While efforts are undertaken to develop new technologies in data collection and processing, the flow of data from providers to users has to be improved. Coordinated by international organisations such as UN OOSA, networks between space agencies, research centers and national organisations should be established to facilitate the provision of satellite data on a global scale. However, equally important for the operationalisation of remote sensing for disaster management are well developed networks between national centers and local actors in the framework of disaster management.

REFERENCES

- CDG, 2001. Human Resource Development in Disaster Management, National Dialogue and Capacity Building Project. Concept Paper for the INGC-UNDP- Carl Duisberg Foundation –Project, Maputo, Mozambique.
- DLR, 2001. Timely Assessment of Floods by using Satellite Remote Sensing Data. Project document, German Space Agency DLR, Oberpfaffenhofen, Germany.
- FEWSNET, 2001. Mozambique Integrated Information Network for Decision Making (MIND). Semi-Annual Report, September, Maputo, Mozambique.
- Gall, M., 2001. Geoinformation for Rapid Flood Assessment and Hazard Mitigation in Central Mozambique. FLAME Mission II, Final Report, www.geo.sbg.ac.at/projects/Flame/.
- INGC/UNDP, 2001a. Lessons learnt from the 2001 floods. Proceedings INGC Workshop, 26-27 July, Beira, Mozambique.
- INGC/UNDP, 2001b. Project of the government of Mozambique "Capacity Building for Disaster Management". Maputo, Mozambique.
- INRC, 2001. Capacity building for vulnerability reduction project. Project memorandum, Italian National Research Council, Maputo, Mozambique.
- JRC, 2002. Digital Map Archive for Humanitarian Relief. Joint Research Center JRC, European Commission, <http://dma.jrc.it>.

Panel of Experts, 2000. Recommendations. Proceedings of the International Conference for Mozambique Floods, 28 October, Maputo, Mozambique.

Steinbruch, F., Gall, M., José, F., 2002. Remote sensing and gis for documentation and evaluation of the socio-economic and environmental impact of the floods 2000 in central Mozambique. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXIV, Part 6/W6, pp. 59-65.

UNDP, 2000. Post Emergency Reconstruction Programme. International Reconstruction Conference, Rome, 3-4 May, www.unsystemmoz.org/index_frame.asp.