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When the Land Tells a Story

Using Geographic Information Systems (GIS) for Landscape Monitoring and Humanitarian Relief

Innovations Case Discussion: Pingree Easement

The Pingree forest stewards devised a scheme to monitor landscape changes over their entire jurisdiction using three key technologies: geographic information systems (GIS), remote sensing (RS), and global positioning systems (GPS). The novelty in the case lies neither in the technology nor the application, but rather in the management setting where the innovation took place.

As Jim Levitt wrote, the size of the easement, the “largest conservation easement project ever realized in the course of American history,” carried with it the significant challenge of tracking landscape changes due to “human population pressures and attendant disruptive environmental impacts” while wisely investing monetary resources in these technologies and human resources. As is true with national parks, designating lands for protection and developing a set of permissible uses is only the start; managers must then find the resources to monitor and enforce those uses. With a finite, albeit robust, budget and personnel who could not always be present, the New England Forestry Foundation (NEFF) distributed a call for proposals to experts in the field of landscape monitoring.

Each group that replied to NEFF employed some aspect of GIS/RS in its plan to monitor and track changes to the landscape of the Pingree forest. Given the

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challenging circumstances of the situation, traditional methods of easement monitoring were impossible: “an individual forester riding around a particular piece of property in a truck would not be economically or physically feasible.” The forest stewards needed to seriously consider an approach that emphasized technology. In the end, the proposal that got NEFF’s attention and approval was one submitted by an academic team including both researchers and students.

The final monitoring protocol, which took shape after the contract was awarded, was built around a multi-scale approach to observation and analysis. That is, observation occurred at three levels: satellite images, aerial photographs, and on-the-ground inspections. Each mechanism provided data on the landscape at a different scope and level of detail. In conjunction with the easement agreements, the monitoring techniques would support the stewards in tracking landscape changes to an agreed-upon baseline; they could then feed these data into the enforcement mechanisms approved in the easement contract in order to ensure compliance. In NEFF’s estimation, the technological solution provided the most cost-effective and practical methods to meet the project’s requirements for landscape monitoring.

The case study itself characterizes remote sensing as a technology “used for more than a decade to conduct surveys of forest conditions around the world” and the algorithms run on images that are supported by “several decades of research.” It is true that products derived from satellite technology and the analytical tools to assess these products have been around for some time. A variety of users, including the military, private companies, and academic researchers, rely on remote sensing to improve their analysis, and thus their decision making and profits.

When the NEFF team evaluated the monitoring requirements of the Pingree forest it understood the need for a technical solution. Since landscape monitoring was the primary need, remote sensing and GIS fit the bill precisely; other technologies, with more impressive functionality, might have had more appeal, but would have been less applicable. In selecting the level of tool for the task at hand, NEFF chose to leverage an existing tool rather than invent a new technology at a significant financial cost. In short, then, the technology itself was not innovative, given its long prior use and strengths in monitoring landscape change.

The governance of this enormous easement demanded a fresh look at techniques and protocols to uphold the spirit and letter of the contract signed by land owners, land managers, and land stewards. The sheer challenge of governing and monitoring the easement could have been enough to derail the entire project—and hesitancy after initial planning meetings made that a strong possibility. But NEFF, working with other interested parties, maintained its commitment to protect the largest forest easement of its kind; together the parties pursued ambitious goals for both fund raising and a viable monitoring scheme.

One innovation within the management setting is worth pointing out: the project included an academic partner in the form of Dr. Steven Sader and his research unit at the University of Maine. The reasons why NEFF selected Sader and his researchers instead of a private company are not explicitly stated in the case but are interesting to understand. We do know Sader’s proposal was “interesting.” The

relationship NEFF developed with Sader's team can perhaps be described as symbiotic; the researchers got the opportunity to expand their own knowledge of GIS/RS applied to an easement monitoring, and to publish a few journal publications along the way. This working relationship between an academic unit and conservationists is a creative way to reach synergy; private industry, especially technology-related fields, has also used it to advantage.

This kind of cooperation between academics, technical experts, and stewards of the earth also occurs among practitioners of disaster response and humanitarian relief. In the rest of this piece we show how this technology, especially these three levels of monitoring, can be applied in a very different set of contexts.

USE OF GIS/RS FOR DISASTER RESPONSE AND HUMANITARIAN RELIEF

Natural processes such as earthquakes, tsunamis, and hurricanes comprise a subset of the causes of landscape change. In the Pingree forest, both natural impacts and human-imposed environmental changes led to landscape changes. The Pingree forest stewards were tasked with monitoring these landscape changes, as set forth in the signed easements. Their responsibilities center on the health of the landscape and of the people living and working there. Similarly, humanitarian relief actors set out to monitor the health, not necessarily of a forest, but of the human population living in an affected environment; they are required to respond when the effects of a disaster cross that health threshold.

The number of people affected by large-scale disasters is growing steadily every year. Factors driving this growth range from simple demographics—the world's population is growing—to complex trends in land use and institutions that result in increasingly dense populations locating in environmentally unstable places.¹ Clearly, humanitarian relief efforts pose a major and intensifying challenge. What is not so clear is how to use available resources most effectively to accomplish humanitarian objectives. In this context, the Pingree case is instructive. We look at how this kind of technology can be, and has been, adopted by response and relief groups, and some of the challenges this adoption presents.

Multiscale protocol and baseline data

The multi-scale approach of the Pingree protocol can be applied widely in humanitarian relief. For example, consider how GIS/RS was used in humanitarian relief to capture the big picture via satellite images, a closer appreciation of destruction from an airplane, and on-the-ground observations. After the Indian Ocean tsunami of December 2004, researchers from Asia, Europe, and the United States compared before-and-after satellite images of Banda Aceh, Indonesia, to determine the extent of damage from on-shore waves.² Using data from the Space Shuttle Radar Topography Mission for the city of Banda Aceh, they could analyze the images and see the elevation of affected areas. Another researcher broke down the area in the Aceh region by land use type; using remote sensing images and topographic maps, he determined the extent of damage to each land use type.³ In addition to moni-

toring landscape change in response to natural processes like waves, relief agencies have used remote sensing to monitor how large refugee populations move and change in size, and how their presence and impact change the landscape.⁴ These are all examples of Level-1 remote sensing.

As an example of Level-2 aerial photography, the Pacific Data Center (PDC) used a hand-held digital camera, in a helicopter, to capture images of flood damage on the Big Island of Hawaii in 2000. They then coded these pictures with time and location information and used GIS tools to analyze the data and monitor the situation.⁵ Within hours after the photo shot by helicopter, the PDC provided annotated damage assessment images via its website; within days, it posted additional images that provided further details on flood damage.

Level-3 on-the-ground inspections are often needed during humanitarian operations. For example, where landmines have been laid, someone must accurately identify their location so non-combatants can travel safely. In one particular survey in Afghanistan, for instance, remote sensing images provided a Level-1 list of possible mine locations based on tell-tale signs

in the landscape: “linear ‘ploughshare’ patterns across patches of terrain, trenches, artificial embankments, fencing (especially along borders), evidence of military activity, and seasonal variations in land use.”⁶ After the monitors examined the possible mine areas in more detail, they could undertake a Level-3 analysis in the field using GPS units.

Thus land monitoring for humanitarian relief bears some similarities to the Pingree project. The first step in the Pingree monitoring protocol was to establish baseline conditions, which could be used to note future changes. Responding to natural disasters requires a kind of double vision: both attention to changes in conditions and a keen interest in the way things are at present. Noting change, like the tsunami’s affects on coastlines, is key to providing aid. But if decision-makers know the locations of villages before a disaster and can compare this information to the situation afterwards, they can better appropriate resources to the areas that

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most likely need supplies and aid. “This process of comparing pre- and post-disaster images is becoming common, in particular as a way of confirming initial estimates of impact and needs assessments.”⁷ In other venues, the baseline data is required less for comparison and more for general awareness of topography, roads, distances, populations, land cover, etc. It is often imperative to have spatial data as background to the present situation. For example, when roads become impassable, transport planners can make better decisions if they know whether or not those roads were paved.

Examples of Projects

Several projects around the world show how this technology can be useful in response and relief work.

The Respond Project. Our first example of how this technology can be valuable is the European Respond project,⁸ which focuses specifically on sharing spatial information. Funded through the European Space Agency, the project’s mission is “to increase the efficiency and effectiveness of the humanitarian community through the appropriate and reliable application of geographic information.”⁹ Combining the expertise of over a dozen organizations, the project began work in December, 2003, after an earthquake struck Bam, in Iran. After the tsunami in 2004, Respond partners produced maps and analyzed high-resolution satellite data covering parts of India and Sri Lanka. While these examples cover the time frame of immediate response, the Respond project also focuses on preparedness and prediction.

Google Earth. After Hurricane Katrina struck the US Gulf Coast in August of 2005, the National Oceanic and Atmospheric Administration used a high-resolution camera mounted on an airplane to capture more than 8,000 images of New Orleans, Louisiana, and nearby areas.¹⁰ Google Earth, a set of visualization tools and spatial data such as maps, aerial photographs, and satellite images available from Google, and a partnership of academic, government, and corporate researchers, used specialized software to overlay other relevant data on these aerial photographs. These images and tools were made available both to humanitarian workers and to the general public.

MapAction. In the last two years, MapAction, a United Kingdom charity,¹¹ responded quickly to several disasters, providing mapping and GIS experts. MapAction personnel were on the ground with GPS units noting locations of key facilities such as hospitals, food warehouses, and roads. They then sent these coordinates by radio back to base camp—perhaps a makeshift tent—where GIS operators incorporated them into digital maps. The maps could then be distributed to humanitarian relief actors working in the area, such as the United Nations and international nongovernmental organizations (NGOs). The group’s maps had a significant impact as the NGOs and other groups responded to the crises in Sri Lanka and Pakistan.

United Nations Involvement. Three UN-related efforts handle spatial data gath-

ering and coordination on behalf of the humanitarian community. The first two are the Geographic Information Support Team (GIST)¹² and the United Nations Geographic Information Working Group (UNGIWG).¹³ GIST, an inter-agency arrangement involving the UN and many partners, promotes the use of spatial data in humanitarian contexts as it identifies data resources, provides a forum for data exchange, and promotes techniques and standards. The mandate of UNGIWG is to coordinate the use of cartography and GIS resources among the UN agencies. A third partner helping coordinate and use GIS in the humanitarian sector is the multiple Humanitarian Information Centres (HICs) managed through the UN Office for the Coordination of Humanitarian Affairs (OCHA).¹⁴ All three UN units acquire, manage, and disseminate GIS, leveraging the power of spatial analysis with GIS/RS tools to meet local needs in times of crisis.

One aspect of this coordination, particularly within the HIC structure, deserves attention here. The HIC is working to assemble a database detailing who is doing what and where so all actors in a given humanitarian effort can distribute resources without duplicating efforts or entirely neglecting a segment of survivors. The HICs also produce spatial products, including maps, contact lists, and data sets with important information about a geographic area. Georgio Santori, a technical manager for field information support in OCHA, describes the ways GIS improves coordination: “These types of operations have been done before with pencil and paper, but new computer technology is speeding up the process. We’re able to process information very quickly and better coordinate our efforts.”¹⁵

A telling illustration of HIC’s work comes from Kathleen Miner, a member of the initial HIC in Kosovo and initial manager of the HIC in Sumatra; she is now with the Humanitarian Information Unit¹⁶ at the U.S. Department of State. She relates how GIS, GPS, and landscape analysis made it possible to relocate tsunami victims who had been buried near existing housing. A young man named Finn approached the HIC about mapping five hastily-dug mass grave sites that held approximately 600 bodies each. None of the graves were marked with anything more than some crude sticks and tape; all were in danger of being “lost.” In fact people were already driving over one grave, not realizing it was there. Local people who owned the houses next to the graves were unwilling to move back to them for cultural reasons; they also knew the decomposing bodies would contaminate their wells. The HIC was able to plot both the mass graves and the proposed reburial plot (an abandoned golf course some distance away) over a satellite image. The resulting image was far more persuasive than any words could be, and resulted in relief workers getting the funding they needed to start moving the bodies.¹⁷

Academic research

Academics are learning to incorporate the power of GIS/RS tools in ways that allow less advanced users to access them. One valid criticism of GIS/RS is that both the data and the available analytical tools are highly technical. Imagine importing these demanding tools into the field during a humanitarian crisis, only to find that

local users, without adequate training, abandon them out of sheer frustration in the midst of an emergency. This situation, together with researchers' desire to see the tools used successfully in the field, has led to a variety of research projects that focus on making the tools usable by field workers and decision makers, not just expert GIS analysts. One project, called GeoWorlds,¹⁸ focuses on the information management potential of GIS; it uses a digital library and visualization techniques to better combine several sources of data. GIS has great capacity to thread several sources of data into a coherent image for analysis; GeoWorlds takes advantage of this by providing less daunting tools for doing so.

Because humanitarian relief work incorporates not only multiple sources of information but also multiple decision makers, other GIS research projects have developed interfaces that make it easier for several non-experts to manipulate spatial data simultaneously. For example, a Greek project called FORTHnet specializes in 3D visualization of land areas while providing support to several users at the same time.¹⁹ A project at Penn State University, called DAVE_G, or Dialogue-Assisted Visual Environment for Geoinformation, recognizes the benefit of having various ways to input data to a GIS system, beyond just a keyboard or mouse. It has been working on large-screen displays of information alongside voice and gesture system commands.²⁰

THE CHALLENGES OF ADOPTING GIS/RS

All the above examples show the great potential for using GIS/RS in the humanitarian sector, but adopting spatial technology into natural disaster management will be neither easy nor automatic. Below we offer several examples of the varied challenges that such implementation has faced so far, and compare them to the Pingree case. We see these challenges as lying in four general areas: economics, the life-cycle of the technology, and issues relating to power and jurisdiction.

Economics

Virtually every agency, in every sector, finds it expensive to acquire the GIS/RS data it needs to have a baseline or a current overview of the situation on the ground. NEFF faced great challenges in managing its own budget and reducing costs. It committed to GIS/RS as a matter of course, but humanitarian relief managers and decision makers can face intense challenges as they prioritize expenditures from among a host of options and proposals. Before they address other economic challenges in choosing the GIS/RS path, even the best-intentioned managers can be derailed by the sticker price alone. On the other hand, some inexpensive—or even free—options are available. One GIS analyst claims that “a disaster manager can get an effective GIS capability in place for only a few thousand dollars.”²¹ A reduced price, however, does not guarantee a successful implementation.

The costs involved in using GIS/RS extend beyond the financial. As the Pingree case showed, acquiring and analyzing data requires a significant investment of time. Even if a project gets past the financial constraints, “there will always be bar-

riers to acquiring timely and accurate data during a humanitarian emergency,” as one humanitarian consultant put it.²²

Humanitarian relief NGOs face a significant constraint on their budgets: many donors expect that nearly every dollar they give to an organization will find its way to a specific project with directly measurable results—and will not be spent on overhead or research. This makes it difficult to earmark monies to fund a GIS proposal that is unknown to donors, however effective it is likely to be. Thus agencies need to adopt thoughtful marketing strategies or write proposals for specific grant monies, targeted for new projects, in addition to their regular budgets. NEFF, at least in the Pingree case, was fortunate to avoid such issues. It moved ahead with its GIS/RS-based monitoring protocol without having to engage in a hard sell with its funders.

This was an appropriate move, as the return on GIS/RS investment for the Pingree forest can be measured in more than dollars; the technological applications have had a huge impact on stewardship of the landscape. But the Pingree forest stewards are realists: they also strive for economic viability and they work within budgetary constraints. Each year they reduce the annual per acre cost of monitoring the land. In the short term, annual costs per acre are higher than required because of endowment parameters. But this very reduction in costs over time represents a long-term gain for the project, which benefits from the initial investment of money and time.

In the context of humanitarian relief, on the other hand, long-term gains fly in the face of current practices. Funders of urgent relief efforts naturally favor immediate action over sustained and incremental returns on investments. The managerial and donor environments support projects that deliver food and shelter over GPS units and GIS software. Others who join this debate rightly question what they see as a disconnect between “relief” and “development”; they call, instead, for a more holistic view, seeing these aspects of the humanitarian cause as part of a larger continuum of intervention.

Holistic monitoring in the full life-cycle

GIS technology can be applied in any or all phases within the full life-cycle of humanitarian relief. This continuum includes several non-discrete phases: mitigation, preparedness, relief, recovery, and development. Francesco Pisano, an advocate of remote sensing, claims that “satellite-based imagery is most useful for relief coordination and information gathering”;²³ he also sees satellite applications as “well worth the investment . . . across the entire disaster cycle, from response to prevention.”²⁴ And he defends the applicability of GIS/RS in development: “we should not underestimate the value of [GIS] and satellite imagery in helping to fill the gap between relief and development.”²⁵

But Paul Currion, a consultant with years of experience covering humanitarian efforts and GIS use, is less optimistic: “It is hard to identify clear success in the implementation of GIS in humanitarian work.... GIS has not proven itself in

humanitarian response, but perhaps it can play a greater role in the ‘before’ and ‘after,’ the preparedness and recovery phases of an emergency.”²⁶ Which position is correct? Simply asking this may miss the point. GIS has not necessarily failed in the humanitarian relief sector. As should be clear from our discussion above and points we will raise below, we recognize the complicated challenges that face humanitarian actors: landscapes and lives undergoing severe stress in volatile contexts amid an uneasy alliance with technology. This same stress applies to all relief workers as they consider effective processes for implementing GIS/RS in any one or more of the phases in the relief-to-recovery continuum.

The humanitarian sector might do well to learn a lesson from NEFF’s long-term monitoring of the Pingree forest; it exemplifies a holistic program of care for the environment, both the landscape and the human populations interacting with the land. Taking the long view, as NEFF has, applies to humanitarian workers as they consider investing the necessary commitment and resources into a program of GIS/RS schemes and protocols. In the end such programs benefit the survivors of natural disasters and the land upon which they rebuild their lives.

We admit it is difficult for internal and external observers to assimilate this long view. As personnel constantly turn over, they take institutional knowledge with them. NEFF has the advantage of being able to leverage the experience curve of seasoned employees who bring their knowledge and expertise to bear on the continued growth of both the organization and the effectiveness of landscape monitoring. In contrast, humanitarian relief workers might contract to three agencies on eight different projects over the course of five years. Similarly, economy of scope—solving a new problem by applying answers developed for an earlier problem—becomes difficult when few if any personnel have the necessary institutional memory. Humanitarian relief workers, writing their final reports, can often be overheard extolling the most recent “lessons learned” in one breath—and in the next breath admitting that a more accurate label might be “lessons documented.”

Power and resistance

Powerful decision makers in humanitarian relief agencies, like those who have country-level oversight of budget and programs, hear sales pitches from GIS analysts or advisers who suggest using GIS/RS in relief programs. The hype—and truth—convinces some decision makers, while others resist, fearing change.

“The next great thing.” “Revolutionary.” Substitute your own hyperbolic descriptor for the labor-saving tool peddled at your doorstep or office mailbox. GIS/RS gadgets provide yet another opportunity for whiz-bang marketers, with their glossy multi-colored maps screaming for attention and financial support. GIS can be—and can be touted as—an all-encompassing tool capable of conducting deep spatial analysis. It can also be just a glorified way to produce slick maps.

Beyond the capacity to generate a pretty map, GIS does not automatically promise analysis. All too often the hype remains just that: “even with high-resolution data, interpreting the imagery to define” the devastated regions is a chal-

lenge.²⁷ Hype may sell a product or convince a manager to funnel resources towards a new GIS project, but few projects benefit as much as they possibly can when GIS technology is not used efficiently.

Decision makers also resist change. In a sector where personnel learn their skills in the fire of disasters, it can take significant force and will to change standard operating procedures. It is too easy to see a high-tech tool like GIS as counter-productive and thus reject it as a possible solution. At the field level, experienced workers may resist changing procedures that allow them to use the electronic tool when other low-tech tools command substantial staying power. Even the Personal Digital Assistant (PDA), which made “the technology more accessible to a wider range of users” in the Pingree case, faces limitations in the field. And some managers simply resist because the technology represents another layer of responsibility and retraining on a new system.²⁸

Jurisdiction

In comparing the Pingree case to humanitarian relief, we also see significant differences in the relevant questions about jurisdiction over land, data, and reputation. Multiple actors participate in humanitarian relief operations while the Pingree forest is monitored and maintained by a limited set of actors. During the tsunami relief efforts governments from around the world pledged financial support as well as personnel transports into Indonesia and Sri Lanka. In addition, the U.N., the European Union, and other multi-lateral organizations provided services of various kinds. And literally hundreds of NGOs, some newly formed after the disaster, inundated villages. At times the relief operations began to remind workers of circuses; some NGOs then attempted to organize the many players while others refocused their energies where they found people under-served. In such a potentially contentious environment, jurisdiction questions beg for procedures to make coordination more efficient—and thus may involve GIS data management capabilities. Beyond the problems of coordination, the issues of legal and de facto jurisdiction in times of disaster operations belong in the hands of international humanitarian law experts.

Moving to the issue of data jurisdiction, we find a similar pattern of disorganized efforts by many actors. Granted, many efforts have been made to coordinate the collection, organization, and sharing of information among humanitarian relief actors. But, as we noted above, in times of disaster more than one organization may collect exactly the same data. Coordination is one factor in this duplication. Another is trust. Can one agency trust the data collection techniques of another agency? What could happen if an agency incorporates information into its decision-making process without clearly understanding whether that data is valid?

Standards, also mentioned briefly in the Pingree case, begin to address these concerns. Several projects are beginning to move towards consensus on standards within the humanitarian sector; among them are the Sphere Project,²⁹ HAP-I,³⁰ the Active Learning Network for Accountability and Performance in Humanitarian

Action (ALNAP),³¹ and PeopleInAid.³² One particular effort related to GIS, the recently-formed Humanitarian Data Model project,³³ seeks to build a complete set of the data points needed for humanitarian relief efforts. Among the types of data points needed are basemaps, hazards, transport, and logistics.

NEFF facilitated the largest easement monitoring project of its time using GIS/RS tools. Will its reputation always include a mention of that achievement? That question remains unanswered now, along with an equally interesting question: which NGO will carry the mantle of the leader in humanitarian GIS efforts? If we can take one lesson from the discussion above, it would be about the creative management of a valuable and powerful tool for monitoring landscapes and conducting sophisticated analysis. The “GIS NGO” will be the organization that demonstrates a new kind of management leadership: not just the ability to use GIS/RS as a high-tech tool, but also the ability to incorporate that tool holistically into a management context. So far no NGO engaged in humanitarian relief has managed to do so.

We invite reader comments. Email <editors@innovationsjournal.net>.

1. Between 1996 and 2005 the mean annual number of persons affected—made homeless, jobless, sick—by natural disasters was 240,250,791. For those years the mean estimated annual monetary cost for natural disasters runs to US\$65.6bn. Source: EM-DAT: The OFDA/CRED International Disaster Database, Universite’ Catholique de Louvain, Brussels, Belgium, available at <http://www.em-dat.net>.

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3. See Chen et al. (2005), op cit.

4.. Einar Bjorgo, Using very high spatial resolution multispectral satellite sensor imagery to monitor refugee camps, *International Journal of Remote Sensing*, 21(3), 2000, pp. 611–616.

5.. Craig Laben, Integration of remote sensing data and geographic information system technology for emergency managers and their applications at the Pacific Disaster Center, *Optical Engineering*, 41(9) 2002, pp. 2129–2136, quote from p. 2132.

6. Kerry Abbott, Geographic information systems in food security and demining programs, *Humanitarian Exchange*, 24, July 2003, pp. 31–33, quote on p. 32. See also Aldo A. Benini, Charles E. Conley, Richard Shdeed, Kim Spurway, and Mark Yarmoshuk, Integration of different data bodies for humanitarian decision support: An example from mine action, *Disasters*, 27(4) 2003, pp. 288–304.

7. Francesco Pisano, Using satellite imagery to improve emergency relief, *Humanitarian Exchange*, 32, December 2005, pp. 36–40; quote on p. 39.

8. See <<http://www.respond-int.org/Respond/>>

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9. Lars Holledig, The Respond Project: Geo-information for humanitarian aid, *GIM International*, 19(7) July 2005, pp. 47-49; quote on p. 47.
10. Illah Nourbakhsh, Randy Sargent, Anne Wright, Kathryn Cramer, Brian McClendon, and Michael Jones, Mapping disaster zones, *Nature*, 439 (16) February 2006, pp. 787-788; quote on p. 787. <<http://www.nature.com/nature/journal/v439/n7078/full/439787a.html>>.
11. See <<http://www.mapaction.org>>
12. See <<http://gist.itos.uga.edu>>.
13. See <<http://www.ungiwg.org>>.
14. See <<http://www.humanitarianinfo.org>>.
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16. See <<http://www.state.gov/s/inr/hiu/>>.
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18. Vished Kumar, Alejandro Bugacov, Murilo Coutinho, and Robert Neches, Integrating geographic information systems, spatial digital libraries and information spaces for conducting humanitarian assistance and disaster relief operations in urban environments, in *GIS '99: Proceedings of the 7th ACM international symposium on Advances in geographic information systems* (New York: ACM Press, 1999), pp. 146-151.
19. Sisi Zlatanova, Andrea G. Fabbri, and Jonathan Li, Geo-information for disaster management: Large-scale 3D data needed by urban areas, *GIM International*, 19 (3), March 2005, pp. 10-11, 13.
20. Ingmar Rauschert, Pyush Agrawal, Rajeev Sharma, Sven Fuhrmann, Isaac Brewer, and Alan MacEachren, Designing a human-centered, multimodal gis interface to support emergency management, in *GIS '02: Proceedings of the 10th ACM international symposium on Advances in geographic information systems* (New York: ACM Press, 2002), pp. 119-124. <<http://doi.acm.org/10.1145/585147.585172>>.
21. Laben, p. 2132. See also Reinhard Kaiser, Paul B. Spiegel, Alden K. Henderson, and Michael L. Gerber, The application of geographic information systems and global positioning systems in humanitarian emergencies: Lessons learned, programme implications and future research, *Disasters*, 27(2) 2003, pp. 127-140.
22. Paul Currion, Better the devil we know: Obstacles and opportunities in humanitarian GIS, January 25, 2006. <http://www.humanitarian.info/?page_id=35>.
23. Pisano, p. 37.
24. Ibid, p. 39.
25. Ibid.
26. Currion.
27. Holledig, p. 48.
28. An illustration of how technology in the field is not always practical comes from an experienced field worker who asked not to be identified. This person has no fear of adopting appropriate technology but chose to leave the PDA at home because of its functional limitations in the typical disaster environment. This person described several constraints: sunlight makes the screen difficult to read, and air-borne particles infiltrate the device; limited access to recharging capabilities makes the PDA hard to power, and it is much easier to use a pad of paper. Personal communication, 3/29/06.
29. See <<http://www.sphereproject.org/>>
30. See <<http://www.hapinternational.org/en>>.
31. See <<http://www.odi.org.uk/alnap/>>
32. See <<http://www.peopleinaid.org>>.
33. See <<http://www.humanitariangis.com/>>.