IDRiM (2011) 1(1)
DOI 10.5595/idrim.2011.0009
ISSN: 2185-8322

Journal of Integrated Disaster Risk Management

Original paper

The Roles and Tasks of Implementation Science on Disaster Prevention and Reduction Knowledge and Technology: From Efficient Application to Collaborative Generation

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Received: 24/09/2010 / Accepted: 05/01/2011 / Published online: 10/05/2011

Abstract Implementation science should be developed and implemented in a scientific manner. Because implementation deals with how well scientific knowledge is implemented in an arena in which more diverse stakeholders rather than only limited number of scientists join, knowledge of implementation science by itself should be developed in a more dialogical and more discursive way. In other words, implementation science is a process to (re-)co-construct knowledge networks in which multiple locally and/or temporarily "viable solutions" co-exist and are mutually interlinked, rather than a process to identify universally "correct solutions" exclusively by scientists. Thus, we need to create a new-type of communication medium by which people can see a society, not as a world where a single "correct solution" is specified by privileged persons, such as a professional scientist, an influential politician, or an talented administrative government officer, for example, but as a debatable, conflicting, and dilemmatic world, and thus, a world where multiple "viable solutions" can coexist. Crossroad Game, a disaster prevention game developed by the author, and Rain Project, a participatory effort for meteorological information sharing that have been developed by Weathernews, Inc., are introduced as two actual case examples of implementation science for disaster risk management.

Key words Implementation science; Viable solutions; Disaster risk management

1. From efficient application to collaborative generation

A number of researchers have pointed out that there are limitations to addressing disaster prevention and reduction only with pure science by researchers primarily in natural science, and that there is need for an implementation science for disaster risk management that is interdisciplinary and comprehensive (e.g., Amendola *et al.*2008; Rodriguez *et al.* 2006). They argue that because the ultimate goal of disaster prevention and reduction is to decrease material, human, economic, and social damage caused by disasters, an implementation science must be established to achieve this goal. Here, implementation

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DOI 10.5595/idrim.2011.0009 ISSN: 2185-8322

science is defined as a science in which effective application of knowledge and skills that have been generated by pure science in implementation sites are taken into account as a subject of scientific discussion. Thus, dissemination and education activities for administrators such as governmental agency employees and general local residents are highlighted in implementation science.

To this end, many techniques have been invented for the general public to learn knowledge and skills about disaster prevention and reduction in participatory, voluntary, and interactive manners, including workshops and creation of disaster prevention maps through town walking (e.g., Na, Okada, & Fang, 2009; Watanabe, 1999; Yamori, 2007). In disaster prevention and reduction implementation that utilizes these techniques, the characteristics of each community and the culture in which they are applied and adapted are often emphasized. Some of these techniques include community-based disaster management (CBDM; e.g., Shaw *et al.* 2009) and participatory disaster risk management (PDRM; e.g., Bajek *et al*. 2008). Furthermore, a database has been developed that contains knowledge and technology concerning disaster prevention and dissemination, and education techniques in forms that facilitate their application (e.g., EDM-NIED, 2006). The CBDM and PDRM are of great significance because these participatory styles of community disaster risk management pointed out the weaknesses of disaster prevention and reduction implementation based on the conventional researcher-centered, non-reciprocal risk communication that is top down from disaster experts to the general public.

Nonetheless, several limitations have been found there as well. The limitations are because, in summary, even if participatory, voluntary, and interactive learning of knowledge and technology is emphasized, unlike in the past, the idea that the knowledge and technology themselves are to be generated solely by disaster prevention and reduction specialists often remains. Put another way, in many cases, even though they are involved in disaster prevention in a more participatory manner, the general public is considered to be only passively learning the knowledge and technology, while specialists prepare the base of knowledge and technology in advance. In other words, how the knowledge and technology concerning disaster prevention and disaster reduction can be effectively applied and adapted on site are indeed given a thorough consideration in the existing CBDM and PDRM. On the other hand, the fact that knowledge and technology per se should be generated bottom up and collaboratively applying wisdom and information from the general public as well as specialists has not been paid sufficient attention to with a few exceptions (e.g., Shiwaku & Shaw, 2008; Yamori, 2009).

It is to be added that collaborative generation of knowledge and technology through joint actions of experts, government workers, and the general public, as a base of implementation science, is emphasized not only in disaster prevention and reduction, but also wider areas of sciences in this modern “risk society” (Beck, 1986). This is particularly the case in advanced, but, at the same time, familiar science, strongly connected to people’s every life, such as biotechnology, organ transplantation medicine, nuclear power generation, etc. A variety of bi-lateral and horizontal communication efforts between science experts and non-experts are aimed at the same goal as the present study including science cafe (Cafe Scientifique, 2011), scenario workshop (The European Awareness Scenario Workshops Initiative, 2003), and outreach communication (Holliman *et al*. 2008),.

2. From “nature vs. humans” to “humans vs. humans”

There are two primary reasons why collaborative generation of disaster prevention knowledge and skills that involving the general public as well as specialists is needed.

The first reason is that as the level of knowledge and technology in disaster prevention and reduction improves and their social application advances, the matter of implementation shifts from being a relationship between nature and humans to a relationship between humans and humans. The traditional subject matter of disaster prevention and reduction, such as constructing banks and dams, making buildings earthquake-resistant and arranging other hardware, and improving communication methods of weather information and arranging other software, are attempts at disaster prevention and reduction basically by humans (society) predicting and controlling natural phenomena, namely, a relationship between nature and humans. This relationship between nature and humans is played within the natural sciences mainly physics and engineering, and assumes the existence of universally correct solutions that hold any time and on any site as I will discuss later in Section 4.4.

However, in societies in which arrangement of such hardware and software is advanced to some extent (typically, industrialized countries), the remaining issues in disaster prevention and reduction center on mutual adjustments concerning conflict of opinions about priority among arrangements of multiple hardware and software, persuasion and negotiation, and attempts to develop agreement, instead. For example, in one area, measures against earthquakes may be prioritized over measures against storms and floods, while the opposite is the case in another area. Moreover, there is a strong possibility that disaster prevention and reduction creates conflict with other social problems. For example, while community residents expect promotion of policies to prevent disaster, the local government may try to prioritize other governmental policies (e.g., education of children and social welfare of older adults) on the ground of insufficient budget. There has been a case in which community residents insisted on preservation of a sand beach that is a resource for sightseeing, while a governmental agency attempted to build seawalls against tsunami expecting their effects on disaster prevention.

These can all be considered to be relationships between humans and humans. Here, no universally correct solution is assumed, and instead, in many cases, the goals are to generate socially viable solutions (discussed in 4.4) that are acceptable to as many stakeholders as possible at the specific sites where they are applied at the moment. In such instances, it is imperative that the general public becomes (co-) agent in generating socially viable solutions in collaboration with specialists in disaster prevention and local governments. Implementation does not proceed well unless the general public accepts the socially viable solutions and personally carry them out according to disaster prevention measures and actions. This is the first reason why collaborative generation of knowledge and technology for disaster prevention which involves the public as well as specialists is needed.

3. Frequent occurrence of localized and short-range extreme meteorological phenomena

The second reason is the occurrence of localized and short-range disastrous phenomena that are hard to predict, such as the phenomenon commonly called “guerilla downpour” which has occurred in recent years. In the past dozen years or so, cases in which very localized extreme meteorological phenomena (e.g., heavy rains and tornados) occur over short periods are increasing in Japan (for example, see Japan Metrological Agency, 2002). So-called “guerilla downpour” is a typical example, which brings heavy rainfall, over 100 millimeters an hour, only to an area that is not any larger than several square kilometers and causes significant damages, such as fatal accidents due to sudden increase of water levels in rivers, flood damage in lowlands and underground shopping areas, and damages due to landslides.

In the Japanese society, the public meteorological observation system centered on governmental organizations with the Meteorological Agency at the core has improved, and meteorological data and research results have been adequately recorded in recent decades. As a result, accuracy of predictions has greatly improved recently as for meteorological disasters that are repetitive, are of an adequate lead time before escalation, and that affect somewhat larger areas, such as typhoons and heavy rains in the rainy season. Consequently, a significant damage reduction has been taken place. For example, the number of deaths per year due to storm and flood damage has sharply decreased to about a tenth in the last 50 years, and recently it is under 100 per year.
Nonetheless, those localized and short-range extreme meteorological phenomena are often difficult to

fully predict and control at least only with the conventional public meteorological prediction system centered on governmental organizations (there have been continued efforts for improvements including adoption of a new type of radar). For instance, a "guerrilla downpour" is caused mainly by a rapid development of cumulonimbus in a very small radius due to several factors such as the heat island effect in urban areas and the rising temperatures of seawaters in the seas near Japan. In the disaster in Toga River in Kobe City, Hyogo Prefecture in 2008 (several deaths), to take an example, the water level rose by 1.3 meters in only 10 minutes. Furthermore, until about 30 minutes prior to the rise of the water level, little precipitation was observed around the disaster site, and it has been found that the heavy rainfall around the basin (upheaval area 7.5 km2) was limited to approximately one hour during which the disaster occurred (Yamori & Ushiyama, 2009). There had been information about heavy rain in a wide area surrounding the site before the incident, but it is believed that providing information (warning) on a phenomenon that evolved in a specific small area in a short period was difficult at that point and would be difficult even today.

Additionally, during extreme phenomena of recent years, disasters (e.g., flood damage) are occurring in expanded areas besides areas where damages have been predicted traditionally (e.g., areas near rivers and meadows). Localized damage affected by microscopic topography, such as a flood in an area that is not much of a lowland on the whole but is depressed very little compared to the surrounding areas is a good example. Therefore, meteorological information at the municipal level (approximately 10-100 km2), let alone that at the prefecture level (approximately 1000 km2), is not sufficiently accurate, and more detailed disaster information is sought for.

To achieve this end, it is necessary for those who live in an area, in addition to public agencies centred on specialists, to familiarize themselves well with the local topographical circumstances (living environment), in addition to paying close attention to rapidly changing meteorological conditions (rainfall and water levels in rivers). Simultaneously, residents are expected to actively detect, collect, and dispatch information about condition changes such as local and urgent disaster information. Then, this information must be integrated with the conventionally existing meteorological information. In other words, residents themselves of an area are required to get involved in activities to generate disaster information that they can utilize to collaboratively generate knowledge, skills, and information with specialists to prepare themselves for localized and short-range disasters.

In the following sections in this article, given that the general public is expected to collaboratively generate knowledge and skills regarding disaster prevention and reduction with specialists for the aforementioned two reasons, I will introduce two actual case examples of implementation of local area disaster prevention that have been developed in that direction. The first example, a game type disaster education procedure, called Crossroad Game, is from my own project (see Yamori, 2007, for example). This relates closely to the first point above concerning the need to shift from "nature vs. humans" to "humans vs. humans." The second example, Project Rain, is being developed by Weathernews, Inc. (Japan) and can be considered to be a project to respond to the second point, the local and short-range extreme meteorological phenomena.

4. Case example 1: Disaster prevention game "Crossroad"

4.1. Interviews

The Crossroad Kobe game is based on actual stories collected from video interviews of Kobe city employees following the Great Hanshin-Awaji earthquake of 1995. In cooperation with the Kobe City Crisis Management Center, 42 group interviews were conducted and recorded in total over a five-year period from 2002 to 2006. The interviews covered a variety of disaster response themes, including how to ensure fire and emergency response, how to set up and manage shelters, how to install disaster response headquarters, how to collect bodies, how to provide food and supplies, how to survey damage to houses and buildings, how to distribute financial compensation, how to restore water and sewage, how to accommodate volunteers, how to build and manage temporary housing, how to address health and sanitation issues, and how to provide support at ward offices.

All interviews were recorded using a digital video camera with the permission of the interviewees. Transcripts are in the process of being written for all 42 sessions (130 hours total), and there are now over 4,300,000 Japanese characters, or 11,000 pages, recorded.

4.2. Creating Scenarios

The transcripts revealed that a common dilemma faced by the interviewees was that making a decision required some kind of trade-off. Many interviewees expressed having to weigh the very difficult reality of solving one problem but creating another: “We had a shortage of shelters and wanted to use school grounds to accommodate people, but that wasn’t an option because we wanted to reopen schools quickly”, “I wanted to report to the office right away, but my family was scared…”, “We needed to survey damages as soon as possible, but at the same time if we rushed, it was sure to invite complaints and redoes later”.

These trade-off narratives form the basis for the disaster scenarios in Crossroad. The theory is that, in thinking about their “Yes” or “No” response to a scenario, players go through a decision-making process similar to that of interviewees, who have since reflected on their past experiences and given them meaning. Please also refer to Yamori (2008) for a theoretical analysis of narratives and the effectiveness of Crossroad games. The fictional scenarios we created for the game were based on actual situations and decisions we extracted from the interview narratives. Since playing time is limited, all of the scenarios are simplified and written in a consistent style. That is, each scenario is under 100 Japanese characters and contained three elements: (a) a description of the job title or position of the decision-maker, (b) a description of a situation requiring a Yes or no decision, and (c) a choice of Yes or No. An example is shown in Table 1.

Table 1 Sample episodes of “Crossroad: Kobe Version”

[Scenario 1] (Kobe Version)

You are: A city employee in charge of temporary housing

Situation: A month has passed after the earthquake. You have been procuring sites for temporary housing for homeless victims. An additional one hundred houses are still needed. Do you use schoolyards as sites?

Choices: Yes (Use the schools) / No (Don’t use the schools)

[Scenario 2] (Kobe Version)

You are: A city employee

Situation: The city hall has almost totally collapsed. However, maps and documents that are vital for disaster response are in the collapsed office. Do you dare to enter the office in the off-limits area?

Choices: Yes (Enter the office) / No (Do not enter the office)

[Scenario 3] (Citizens’ Version)

You are: A citizen

Situation: City officials are considering a list of people in need of nursing care to distribute to volunteers and communities in case of disasters. Do you support the idea?

Choices: Yes (Support the idea) / No (Do not support the idea)

4.3 Rules of the game

The Crossroad game kit contains large scenario cards each presenting one description of a problem scenario (See Figure 1; 20-30 cards total), Yes and No cards for each player, game point cards, and an instruction handbook. The handbook includes the rules of the game, excerpts from the actual narratives upon which the scenarios are based, statistical and other data related to the scenarios, and notebooks ("Crossnotes") in which participants can record the reasoning (or apprehensions) behind their own decisions as well as those of others. In addition, when my team and I act as facilitators, we also give a more detailed PowerPoint presentation and, in some cases, show footage of the interviews.

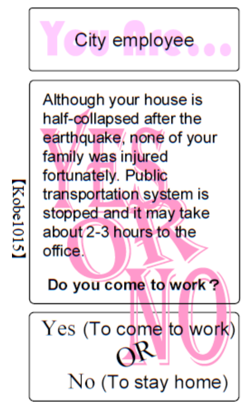

Figure 1. Crossroad problem cards

The procedure for playing Crossroad is as follows (summary shown in Figure 2):

(1) A game should have 5-7 players.

(2) Rotate the person who reads out the scenario card for the group.

(3) Each player makes a Yes or No decision in response to the scenario that is read (1 minute to decide).

(4) Simultaneously, everyone must hold up either their Yes or No card to indicate their decision.

(5) Calculate scores for each player. One standard point (blue poker chip) is awarded to all players with a majority opinion. If there is only one person in the group with a minority opinion, one special point (gold poker chip) is awarded. No points are awarded if there is more than one player in the group with a minority opinion.

(6) Each player orally presents the reasons for his/her decision and then everyone discusses as a group. (This step may take various forms: go around in order, leave the minority opinion for last when there is only person, set the discussion up as a debate, do a re-show of Yes or No cards

after everyone presents, etc.)

(7) Read/listen to the narratives presented in the instruction handbook.

(8) Repeat steps 3 through 6.

(9) As needed, record the proceedings in the “Crossnotes” either individually or as a group.

(10) If several groups are playing, end the exercise by having each group make an oral presentation on the results of their game and discussion. (Make visual aids to illustrate the results if possible.)

The total amount of time required to play depends on the number of problem cards used. Depending on the level of background knowledge and interest of the players, it may take from ten minutes to over an hour to complete one scenario card (steps 1-10). In general, disaster prevention specialists or other individuals who are knowledgeable about disaster prevention tend to require more time while college students and others who are unfamiliar with disaster prevention tend to require less.

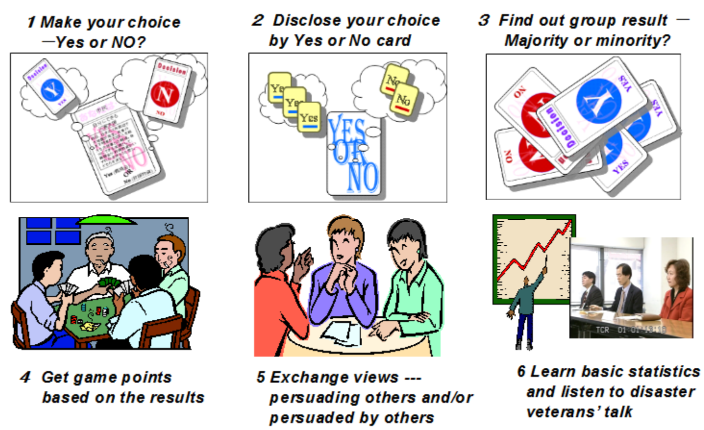

Figure 2. Crossroad game rules

4.4. “Correct” and “viable” solutions

In this section, I consider the significance of Crossroad in terms of the concepts of universally “correct” and socially “viable” solutions. (See Okada, 2008 for discussion of these concepts.)

As the case study demonstrates, the point of participatory disaster prevention exercises using Crossroad is not for specialists to transmit “correct” information that is universally true for any given time or place. Rather, the objective is for researchers, government, and local residents to mutually agree on solutions that are viable, that is, that can be materialized and received, in particular localities. In other words, the purpose of Crossroad is not just to identify and transfer the lessons learned from the Great Hanshin-Awaji earthquake about “correct” disaster prevention and preparedness. By presenting the Hanshin-Awaji experience as one example of how “viable” actions were taken, participants in the game can have a point of comparison for considering disaster prevention in their own towns and work together to form their own viable solutions.

Viable solutions are not universal and are always local and temporary. Therefore, any agreements or solutions that come out of Crossroad must necessarily be open to revision and improvement. What is viable in the field now may not have been or may not be viable at a different time or in a different place. The conclusion we can draw from this is that Crossroad is not like traditional disaster prevention exercises in which experts lecture on what is right, with the implication that anything else must be wrong. In fact, the philosophy behind the game is that an idea that was not viable before may be viable now but may or may not be in the future, or in reverse, that an idea that may have been viable in the past or may be viable in the future may not be viable for the situation now. Even if an idea cannot be applied to the situation at hand, it should not be dismissed, but instead preserved as a potentially viable solution for the future.

To close this section, two important points are raised about viable solutions. First, viable solution is not incompatible with correct solutions, but these two different types of solutions are mutually complementary to each other. In natural sciences regarding disaster preventions and reduction, such as seismology, hydrology, and meteorology, it is realistic and desirable to assume correct solutions which are universally true regardless of who do research, and when/where research is done. However, in human sciences, which implementation science must join hands in cooperation, it is virtually impossible to assume correct solutions which can take all the individual, inter-societal, and cross-cultural differences in preferences, attitudes, and evaluations toward particular disaster reduction measures. Implementation science must consider these changes over time as well. In such conditions, a dynamic process, in which viable solutions are recreated and replaced over time and place, is important, although the whole process is under a certain control which correct solutions impose.

Secondly, viable solutions are different from contingent solutions. When people say contingent solutions, it is considered that currently contingent solutions will be and should be developed eventually into universally correct solutions with a proper research effort. In this sense, contingent solutions are a part of, more precisely, in a limited form of, correct solutions. However, as clearly indicated in Crossroad gaming, viable solutions are never expected to develop into correct solutions. Instead, a viable solution, e.g., a consensus made in Crossroad, is supposed to shift into another viable solution, in response to the changes in physical and societal environment and changes in preferences, attitudes, and values of stakeholders. Therefore, in viable solution approaches, it is not critically important whether or not a viable solution (consensus) is formed at the present time. Instead, the important factor is to maintain a continuous drive from the present moment toward constructing a future viable solution (consensus). An endless and dynamic movement toward another viable solution (consensus) is emphasized here instead if a static state of viable solution (Yamori, 2007).

5. Case Example 2: Project Rain, Weathernews Inc.

The second example is a number of participatory efforts for meteorological observation and disaster information sharing that have been developed by Weathernews, Inc., such as Project Rain. Here, I will illustrate Project Rain, which reached its fifth year in 2009, as an example. Weathernews (2009) explained Project Rain as follows: "Project Rain reached its fifth year this year having developed '10 minutes Weather Forecast' in which we aimed to make observation of location and force of rain clouds with the public, reflect the information in real time, and to attempt meteorological prediction by smaller units of time last year. This year, to grasp the seasonal rain front accurately, whose actual state is believed to be difficult, we at Project Rain will tackle integrating the information from phenomenological sensibility that only those who live in the area can acquire, figuring out the future weather and the accurate force and location of the seasonal rain front, and promptly sharing the information with the consumers."

The "public" and "consumers" who are referred to here are 40,000 Weather Reporters throughout

Japan who announced their participation in this project and registered as members. Needless to say, these Weather Reporters are only ordinary people, instead of specialists in meteorology or disaster management. Weather Reporters join the project in a completely voluntary base without having any monetary reward. In return, they can access the company's website to check nationwide, regional, and very local weather information. They report on appearance of clouds, rainfall, and so on using mobile phone e-mail (of course, this is not to say that, with exceptions, they actually measure with observation apparatus such as a rain gauge, but they report subjective judgments about such points as severity of rain based on classification categories identified by the company). In these instances, by using the geo-location system of the mobile phones, all of the information with accurate latitude and longitude is gathered at the company's information centre. The results of these subjective observations through human five senses, rather than objective observations through apparatus, by Weather Reporters are utilized to specify the location of seasonal rain front and predict a guerilla downpour as described before (very short-range forecast of the weather for the next 10 minute).

However, the company's weather information does not of course solely depend on Weather Reporters' subjective observation information. The objective information collected through the infrastructure of Weathernews, inc. (weather radar and observation apparatus) and data observed and issued by professional agencies (e.g., the existing weather forecast agency, Japan Meteorological Agency) is fully applied as well. The information gathered through its observation network which is primarily composed of the general public (Weather Reporters) is applied additionally to understand and predict very localized and short-range weather conditions. The company's weather information is generated as a collaboration product of the two and delivered to customers of the company's services including the Weather Reporters who are also senders of the information immediately via e-mail.

Certainly, questions about preciseness, reliability, and accuracy of reports of the subjective observation by the general public have been voiced. The most serious one is about the possibility that a reporter intentionally reports false information. The company's argument against this point is as follows: The reporters operate after registering themselves with personal information such as name and address in advance, and the possibility of false reporting is lower compared to anonymous operation. In addition, there are tens of thousands of Weather Reporters throughout Japan, and other observational apparatuses are used alongside and therefore, obviously false reports and erroneous information can be eliminated by cross-checking information. Furthermore, the company emphasizes that generally in the majority of the cases, reporters find rather altruistic satisfaction and a sense of reward in their tasks (such as information gathering and dispatching) as seen in the feedback: "I am glad that my contact alone could generate weather information that might benefit many."

Additionally, it is important that these subjective observations are not carried out only in critical situations in terms of disaster prevention, but the same kinds of participatory information collection network is utilized with more ordinary themes that are ingrained in users' lives also, for example, prediction of blooming of cherry, surveying distribution of a type of cicada, and understanding the volume of pollen in the air. With these strategies, the company's projects have succeeded in merging Project Rain into the everyday lives of ordinary people, instead of presenting it as an out of ordinary, special project. At the same time, everyday use provides a mechanism of regular and constant maintenance of the apparatus and network system for information collection and dispatch.

Overall, I consider that Project Rain can be appraised positively, although not free from problems such as above, as a highly unique effort to collaboratively generate disaster information concerning local and short-range extreme weather through collaboration between specialists and the general public. The company presents a phrase, "Join and Share" as the principle of Project Rain. This suggests precisely that a platform of knowledge, information, and technology where the general public and specialists can share and be collaboratively involved in is exactly what is critical to current disaster prevention and reduction. This is not aimed at effective application of knowledge and technology that have been generated by pure science in implementation sites of disaster prevention and reduction, but rather, constructing new social systems for knowledge, technology, and information production. More specifically, the development of tools and programs that serve as a platform, such as Crossroad and Project Rain illustrated in this article, are required in implementation science for disaster prevention and reduction, in addition to advancing knowledge, technology, and information regarding disaster prevention and reduction.

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DOI 10.5595/idrim.2011.0009
ISSN: 2185-8322

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