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Original paper

Feedback Process of a Tsunami Evacuation Plan Using Quantitative Data of Drills for Supporting Vulnerable People in a Community

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Abstract To prepare evacuation plans, including an evacuation support system for vulnerable people such as the elderly, injured, pregnant, or other people requiring support during a tsunami evacuation, validating evacuation drills with respect to real-world circumstances using quantitative data is important. This study aims to clarify the importance of using evacuation drill data for evacuation planning. To this end, we measured the movements of residents during an evacuation drill conducted according to a set plan in a community and verified the observed quantitative data. We have been supporting the drills and community disaster management plan (CDMP) in the Shinyo Community of Kobe City since 2008 and hence selected this community for our study. We measured the residents' evacuation time and speed using various transportation modes to transport vulnerable people to safety during the drill and verified the evacuation plan's effectiveness. Quantitative data were verified in the drills and vulnerable people and their supporters, who were measured on this occasion, were evacuated from the tsunami warning area within the estimated tsunami hitting time for Hyogo prefecture of 90 min after the earthquake. Further, using four types of transportation modes—a rollator (wheeled walking aid), transport chair, wheelchair, and cart—yielded conveyance speeds (average of the time taken by a vehicle to traverse the entire evacuation route, excluding wait times at traffic signals) of 1.03, 1.42, 1.50, and 1.27 m/s, respectively. Few days later, the participants provided feedback on the drills in an evaluation meeting and deemed the evacuation plan effective. This study presents a progressive thought process that utilizes the interaction between "planning" and "training" to enable a feasible CDMP to combat disasters.

Key words: Tsunami evacuation plan; Vulnerable people; Drill; Community.

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1. BACKGROUND

To develop an evacuation support system for vulnerable people during disasters, an evacuation plan must be drafted based on the actual circumstances of local communities. Therefore, the mutually dependent processes of "training" and "planning" are essential; the effectiveness of an evacuation plan can be measured by training, and its results will be reflected in the subsequent plan. Herein, we present the results of tsunami evacuation training based on a community disaster management plan (CDMP; Kobe City 2018), created by the Shinyo Community in collaboration with the local government based on the Disaster Countermeasures Basic Act (1961, Amendment 2014) and their influence on the subsequent plan by considering the Shinyo District, Nagata Ward, Kobe City, Japan, as an example.

In the wake of the 2011 Great East Japan Earthquake, 16.1% of the deceased or missing people were observed to be vulnerable people; however, the people who supported those vulnerable people constituted 18.9% of the missing or deceased populace. Therefore, 35% of the missing or deceased people were either vulnerable themselves or related to vulnerable people (Isozaki 2013). Therefore, a considerable number of district welfare commissioners, members of the volunteer fire departments, and others who supported the evacuation became victims along with the vulnerable people.

Another great earthquake is expected to occur in the future, which will originate in the Nankai Trough; the number of deaths is predicted to be ~323,000 in Japan (considering a case in which the Tokai region suffers considerably). Furthermore, ~230,000 of these deaths will be caused by the ensuing tsunami (Cabinet Office 2012). The population of supporters aged under 65 years is decreasing in Japan (National Institute of Population and Social Security Research 2017). In contrast, the population of vulnerable people aged 65 years and above is increasing. In this aging society, considering the increasing number of vulnerable people accompanied by increasing burden on their supporters is important. Therefore, an evacuation support plan must be established as a countermeasure against disasters to rescue vulnerable people (Fire and Disaster Management Agency 2013). Additionally, the total evacuation time required to reduce the danger to human lives belonging to all age groups, including people acting as supporters to vulnerable people, should be understood. The total evacuation time is the sum of the evacuation preparation time and evacuation action time of each group comprising both vulnerable people and their supporter(s); it represents the duration between earthquake occurrence and the completion of evacuation.

Existing studies related to this topic are summarized in the following paragraphs. Liu et al. (2006) demonstrated, in a study involving quantitative data analysis, that the most appropriate evacuation route can be calculated using the spatial temporal geographic information system DiMSIS to minimize the total evacuation time in the case of flood disasters. Using the Shinyo District as an example, they modeled evacuation route selection by considering actual city blocks and performed a computer simulation of the evacuation.

Based on a dynamic control model for evacuation vehicles, a previous study investigated the use of automobiles to reach facilities to support the evacuation of vulnerable people from tsunamis (Urata and Hato 2017). However, that study only used computer simulation with no practical verification. Therefore, the applicability of Urata and Hato's (2017) study to practical scenarios is uncertain.

Another study involving qualitative analysis investigated a five-year project on community-based resilience against environmental disasters, such as floods, droughts, and forest fires in Ghana (Antwi 2014).

Furthermore, local Inclusion Support Centers have conducted a field study on support enhancement for vulnerable people in the disaster area of the Great East Japan Earthquake (Minemoto 2013); a qualitative analysis based on case studies was conducted in that study.

However, to the best of our knowledge, no studies have been conducted thus far in which a plan developed by the residents belonging to a community was verified using the obtained data. Furthermore, no reports are available related to the training of local residents based on experimentally obtained results or related to efforts that contribute to reducing the damage caused by future disasters in the local community.

Compared to Liu et al.'s (2006) work, the novelty of this study is that it was conducted using real data instead of simulated data, e.g., the evacuation training was tested in highly realistic disaster situation by actual residents of a community. In addition, evaluation meetings were conducted with the residents to discuss and mutually reflect on the community disaster management plan (CMDP), district disaster prevention plans, and evacuation drills.

Therefore, the objectives of this study are to emphasize the importance of tsunami evacuation drills being conducted from each house or company to the nearest evacuation point, with the residents navigating the streets to reach the closest evacuation point, and investigating various potential scenarios for a district. In this study, the time taken for evacuation (i.e., the speed of evacuation) is measured and verified based on the plan.

Previously, many CDMP or other types of disaster management plans existed, which only showed the assumed tsunami inundation area; however, few plans are available that consider the time taken by the residents (i.e., evacuation speed) to evacuate the affected area. Furthermore, some experiments have previously measured the evacuation time (speed) required for supporting vulnerable people; however, cases where evacuation was successfully implemented with that speed in the community could not be found.

This study not only provides technological approaches involving quantitative data but also investigates sociological influences on evacuation scenarios. Possibly, a pragmatic plan can be developed for verification and interaction with two approaches. The interaction between "planning" and "training" could also improve the CDMP. This is a pioneering caveat of this study.

2. EVACUATION AREA IN THE PRESENT STUDY

Various means can be used to protect human lives from tsunamis (see Figure 1). In the following sections, we describe the evacuation methods and region considered in the present study.

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2.1 Ways to avoid tsunami-related hazards

To reduce the damage caused to human life by tsunamis, various types of countermeasures are being developed; these measures include the construction of embankments and the development of a system to transfer groups of people to higher ground in advance (Figure 1(a)). Furthermore, alarm systems are being developed to ensure early awareness.

However, all residential coastlines in Japan cannot be protected using embankments. In a project related to group transport for disaster avoidance, 139 municipalities deemed at risk of tsunami disasters (according to the Act on Special Measures for the Nankai Trough Earthquake) have been designated as “tsunami evacuation special strengthening areas.” Furthermore, the subsidies for such relocation promotion projects have also been increased, although these projects have not been applied by any municipality as of March 2018 (Mainichi Newspapers 2018). Thus, evacuation actions are becoming increasingly necessary for protecting the life of residents.

2.2 Types and means of evacuation and future subjects

With respect to evacuation from tsunamis, evacuation sites can be classified into two categories: evacuation to the upper floors of a building (Figure 1(b), hereafter referred to as “vertical evacuation”) and evacuation to higher ground outside (Figure 1(c), hereafter referred to as “horizontal evacuation”).

In the case of vertical evacuation, elevators may stop functioning in some cases. Therefore, using stairs should be considered as the principal means of evacuation. Evacuees can climb the stairs themselves or with assistance; furthermore, vulnerable people can be carried up the stairs using equipment such as wheelchairs, chairs, or cloth stretchers. For horizontal evacuation, a wide range of outdoor evacuation methods can be used in a city area: independent walking, assisted walking, and transportation using wheelchairs, stretchers, carts, bicycles, or automobiles.

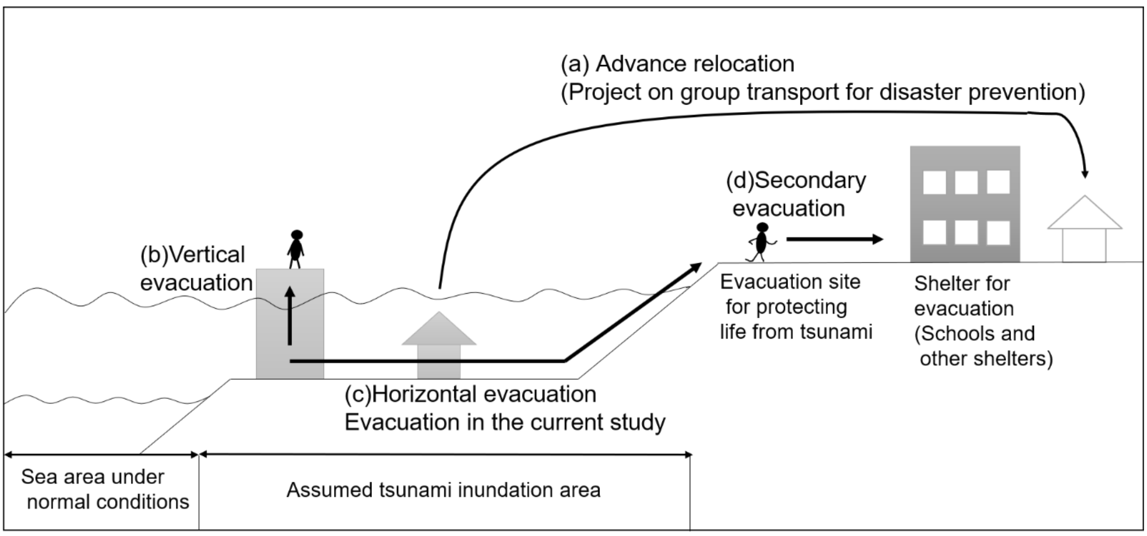

Figure 1. Various means of protecting human life during tsunamis

With regard to vertical evacuation, the possibilities of tsunami fires and isolation within buildings are assumed herein. With regard to horizontal evacuation, congestion of evacuees and a decrease in the evacuation speed owing to a blockage on the evacuation route are assumed because long-distance movement is required during such evacuations.

A common subject in both vertical and horizontal evacuations is that many vulnerable people must be evacuated to higher ground as early as possible with few human and material resources. The present study explores horizontal evacuation.

2.3 Evacuation using automobiles and the risk of traffic congestion

Evacuations can be conducted using either human power or an automobile. Because evacuation using automobiles may cause traffic congestion, herein, we discuss evacuations that utilize human power.

For example, in the 2011 Great East Japan Earthquake, 115 cars (38% of the 303 cars that have been inspected as part of investigations related to evacuations via automobiles) in Ishinomaki City, Miyagi Prefecture, Japan, were stuck in traffic congestion (Yanagihara and Murakami 2013).

Kobe City, which is considered in the present study, is located in the Hyogo Prefecture, Japan. Hyogo prefecture contained 2,297,983 private cars at the end of March 2009 (Automobile Inspection & Registration Information Association 2017), whereas Miyagi Prefecture contained 1,164,630 private cars at the end of March 2010 (Automobile Inspection & Registration Information Association 2010). The density of private cars in the Hyogo Prefecture was 273.53879 cars/km^2 (Automobile Inspection & Registration Information Association 2017; Geospatial Information Authority of Japan 2017), whereas that in the Miyagi Prefecture was 169.71893 cars/km^2 (Automobile Inspection & Registration Information Association 2010; Geospatial Information Authority of Japan 2011). Compared with the Miyagi Prefecture, where human life suffered owing to traffic congestion during evacuation by car, the Hyogo Prefecture exhibited a higher number and density of private cars. Therefore, in the present study, we investigated evacuations that utilize human power.

2.4 Time axis and definition of “evacuation” in the present study

The term “evacuation” signifies two meanings when it is approximately classified based on the purpose of evacuation and time axis. The first meaning includes the “evacuation behavior” (Figures 1(b) and (c)) toward the “evacuation site” or “evacuation goal” that protects lives from direct disasters such as fires and tsunamis. The second meaning includes the actual “movement” of affected people (Figure 1(d)) to “shelters” and other such facilities, particularly in the case when a person must spend his/her daily life at the shelter or any place other than home while avoiding secondary damage. From the perspective of the time axis of disaster cycles, such as emergency response, recovery/restoration, disaster mitigation, and disaster prevention, the former meaning of evacuation is limited to the response stage, whereas the latter meaning covers activities ranging from response to recovery/restoration.

In the present study, we deal with a process through which a community prepares and verifies a horizontal evacuation plan (see Figure 1(c)) in the early response phase that focuses on evacuation behavior to protect lives from potential direct disasters, such as tsunamis and other such events.

2.5 Community disaster management plan (CDMP)

A CDMP is a plan involving the voluntary cooperation of residents or companies in a certain area of a municipality to perform disaster prevention activities based on the Disaster Countermeasures Basic Act. In Japan, CDMPs have been formulated comprehensively and from a long-term perspective at the national level of the Disaster Management Basic Plan; CDMPs have also been formulated by prefectural and municipal governments at the local level of local disaster management plans. In the event of a large-scale disaster that paralyzes the administrative functions of municipalities, protecting oneself and helping others within the community is important. During the Great East Japan Earthquake, people recognized that without a cooperative outlook regarding self-help, mutual-help, and public-help, disaster measures would not be entirely successful. Therefore, following the 2011 Great East Japan Earthquake, a CDMP was added to promote the practice of mutual-help in communities. In the 2013 revision of the Disaster Countermeasures Basic Act, some provisions concerning self-help and mutual help were added (Cabinet Office, 2014). The aim of the CDMP is to improve local disaster prevention capabilities by strengthening mutual help in communities. Internationally, it is considered to be an advanced initiative, and its future scope is attracting attention.

3. METHOD

We initially verified the effectiveness of the evacuation plan by training. We considered the example of Shinyo District, Nagata Ward, Kobe City, as an example. Furthermore, we described the mutual interaction between “planning” and “training,” wherein the training results are incorporated in the form of improvements in the subsequent plan.

3.1 Outline of the method

We have been supporting the training and the preparation of CDMP in Shinyo District, Kobe City, Japan, since 2008. In Shinyo District, the Shinyo Disaster Prevention Welfare Community [Shinyo Bokomi (note1)] has been active as a voluntary disaster prevention organization since 1996. It is a voluntary organization that organizes disaster responses among residents. In this district, evacuation training is conducted every year. In 2012, evacuation training was conducted for ~400 kindergarten children; this training was supported by the disaster prevention welfare community. Thereafter, a new subject emerged, related to the means by which vulnerable people, such as kindergarten children, elderly people, and others for whom independent evacuation is difficult, could be evacuated. The district evacuation plan for this area was prepared in 2014 based on community consensus; this plan included a point according to which vulnerable people should be transported used wheelchairs and other such measures.

We initially conducted experiments at the Research Center for Urban Safety and Security, Kobe University, using the transportation means that were included in the CDMP and collected data related to the transportation speed of vulnerable people. In addition, we inspected and verified the effectiveness of this plan by measuring the transportation speed of residents during evacuation training in Shinyo District. The obtained data were evaluated through evaluation meetings, and the evaluated results were reflected in the subsequent plan.

Furthermore, we verified the effectiveness of the evacuation plan according to the four items listed in Table 1.

Table 1. Verified items and benchmarks of the training

Verified Item	Content
A	Can four kinds of apparatus (wheelchair, transport chair, rollator, and cart) be used to support the evacuation of vulnerable people?
B	Is the total evacuation time shorter than the risk-spreading time? Is the t-value: "$t_{\text{hazard affect}} > t_{\text{total evacuation}}$"?
C	To support vulnerable people, should we move from a safe area outside an assumed tsunami inundation area to a dangerous location inside the area?
D	After completing the evacuation of the first vulnerable person, should the supporter return to the tsunami inundation assumption area and help to evacuate the second vulnerable person? Is the t-value: "$t_{\text{hazard affect}} > (t1_{\text{total evacuation}} + t_{\text{return}} + t2_{\text{total evacuation}})$"?

3.2 Overview of the district

The district where the investigation was conducted can be described as follows. Shinyo District is located in the coastal area of Japan (see Figure 2). During the massive Nankai Trough earthquake that is expected to occur in the Pacific Ocean near Japan in the near future, the tsunami is expected to arrive 90 min after the earthquake strikes and tsunami waves' height is estimated to be ~4 m (note 2) in the district.

Table 2 lists the population, number of households, and aging rate (percentage of people over 65 years of age in the total population) in Shinyo District. The aging rate is provided in Table 2 because the majority of vulnerable people are elderly. Regional age statistics are also provided in Table 2; however, no statistics on vulnerable people were available.

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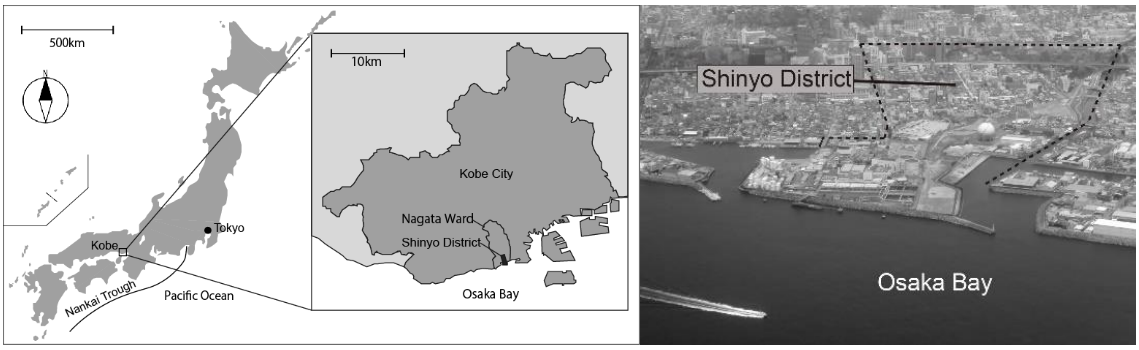

Figure 2. Location (left) and aerial photograph (right) of Shinyo District
(Source: Ohtsu and Hokugo 2017).

Table 2. Housing situation in Shinyo District

	Shinyo District	Whole country
Population	5,896 (a)	
Number of households	3,036 (b)	
Average number of persons in a household (people)	1.94 (a/b)	2.51
Aging rate (%)	30.7	23.0 (FY2010)

"Comprehensive Survey of Living Conditions (FY2013)" by the Ministry of Health, Labour, and Welfare
Number of households and age (5-year step) per municipality in Kobe City (Census)
Results of the FY 2010 census (as of October 1, 2010)

3.3 Plan outline and preparation process

The CDMP describes the procedures of Bokomi activities for organizing disaster responses. With regard to the time axis of the disaster cycle, the activity flow at the community was observed to focus on the "prevention" and "response" phases. In the present study, we focus on the planning and data reflection of "evacuation support for vulnerable people in case of a tsunami" in the initial phase of "response."

Table 3 presents the details of the meetings on CDMP preparation and training evaluation in Shinyo District. Three meetings were held on CDMP preparation, and the related summary report was completed in December 2014. This report, comprising 23 pages, first describes fundamental information such as the standards for establishing the Bokomi headquarters, the activity policy, and the resources for disaster prevention (materials and cooperative offices). Subsequently, the report provides a checklist-type action manual that describes disaster-specific actions, including those for earthquakes, tsunamis, storms, and floods. Finally, it describes "advance activity instructions," which simplify the evacuation process on the day of an actual disaster. Horizontal evacuation during a tsunami is mostly described on pages 9–11 and 18–23.

With regard to the meetings related to CDMP preparation of the Shinyo Bokomi, the following three points were considered noteworthy:

(1) A member of a fire department took charge as the facilitator. However, the facilitators in each group were not consultants but volunteer firefighters, who formed the core of the disaster prevention effort in the district (Figure 3). Because the plan was prepared for large-scale disasters in which public assistance was impossible, the discussion was

limited to what could be performed by the people who would be working in the district during a disaster.

(2) The meeting attendees were members of 19 self-governing associations in Shinyo District that participated in the Bokomi, including the following committees: The consumer committee council, youth development council, women's association, parent–teacher association, children's board, elderly association, fraternity visit group, probation board, shopping street associations, markets, hospital boards, volunteer fire departments, and the Parishioner's Board of the Nagara Shrine. Because people from various organizations that were active in the district participate in the Bokomi, the CDMP could be easily extended to the community.

(3) Even if a plan was completed, it would not be effective unless the public was notified. In the case of the Shinyo Bokomi, 23-page booklets describing the plan were distributed to ~3,000 households in the district.

Figure 3. Member of the volunteer fire department (center) taking charge as the facilitator of the group.

Table 3. List of meetings on CDMP preparation and training evaluation.

	1st meeting on CDMP preparation	2nd meeting on CDMP preparation	3rd meeting on CDMP preparation	Evaluation meeting 2015	Evaluation meeting 2016
Date	29-Aug-14	25-Sep-14	22-Oct-14	3-Mar-15	21-Feb-16
Place	Shinyo Elementary School Library	Shinyo Elementary School Library	Shinyo Elementary School Library	Shinyo District Welfare Center	Shinyo District Welfare Center
Sponsorship	Shinyo Bokomi	Shinyo Bokomi	Shinyo Bokomi	Shinyo Bokomi	Shinyo Bokomi
Attendance	Total: 50 people Bokomi: 29 people (including 19 residents' associations) Elementary school: 2 people (principal and vice-principal) Volunteer fire corps: 11 people Fire Bureau: 6 people Ward Office: 2 people	No data	Total: 47 people Bokomi: 26 people (including 19 residents' associations) Elementary school: 2 people (principal and vice-principal) Volunteer fire corps: 11 people Fire Bureau: 6 people Ward Office: 2 people	Total: 15 people Bokomi: 11 people Fire Bureau: 1 person Kobe University: 3 people	Total: 29 people Bokomi: 24 people Fire Bureau: 1 person Kobe University: 4 people
Facilitator	Total: Fire Bureau Group: Volunteer fire corps	Total: Fire Bureau Group: Volunteer fire corps	Total: Fire Bureau Group: Volunteer fire corps	Kobe University	Kobe University
Main content	・Information sharing with regard to previous disasters in the district ・Information sharing regarding the outline of the plan ・Preparation of the basis for the plan	・Distributing the activities' time between self-help and mutual assistance ・Revision of the basis for the plan	・Selection of actions that can or cannot be supported by the Bokomi ・Determination of the plan	Items A–D in Table 1 were verified.	Items A–D in Table 1 were verified.

3.4 Outline of training

Table 4 presents an outline of the training and experiment that are the objects of this study, in terms of the interaction between the feedback process and planning. Following a request by the Shinyo Disaster Prevention Welfare Community, which intends to formulate a plan, Kobe

University, which has conducted evacuation research for a long time, began to cooperate with them to verify the effectiveness of the evacuation plan.

Table 4. Training and experiments related to the investigation.

No.	1	2	3
Schedule	5 days between December 18, 2014, and May 1, 2015.	17-Jan-15	17-Jan-16
Title	Measurement by experiment	Measurement in training	Measurement in training
Place	Experimental course at the Kobe University	Shinyo District	Shinyo District
Inspected item (refer to Table 1)	A	A, B, C, D	A, B, C, D
Data	Data1	Data2	Data3

4. RESULTS: REFLECTION ON THE PLAN AND TRAINING

Figure 4 displays a flowchart that reflects both the plan and training for the CDMP that was completed in 2014.

Bokomi members deemed the improved plan to be comprehensive while considering both quantitative and qualitative data, based on whether the verification items listed in Table were available. Here, quantitative data refers to the data obtained in the experiment or training such as evacuation speed or time. Qualitative data refers to the feedback provided by the participants at the meeting.

4.1 Verification Data 1

The evacuation speed data obtained in the experiment (refer to entry No. 1 in Table 4 and Table 6) and the data demonstrating the potential transportation of vulnerable people in the same experiment are collectively referred to as Data 1 in this study. These results were presented to the residents at the meeting on CDMP preparation, and Data 1 were discussed and verified.

Experiments were conducted to determine whether vulnerable people could be transported using three vehicles (i.e., wheelchair, transport chair, or rollator) listed as transport means in the CDMP. Experimental results revealed that all three vehicles could be used; furthermore, we obtained data related to their speeds.

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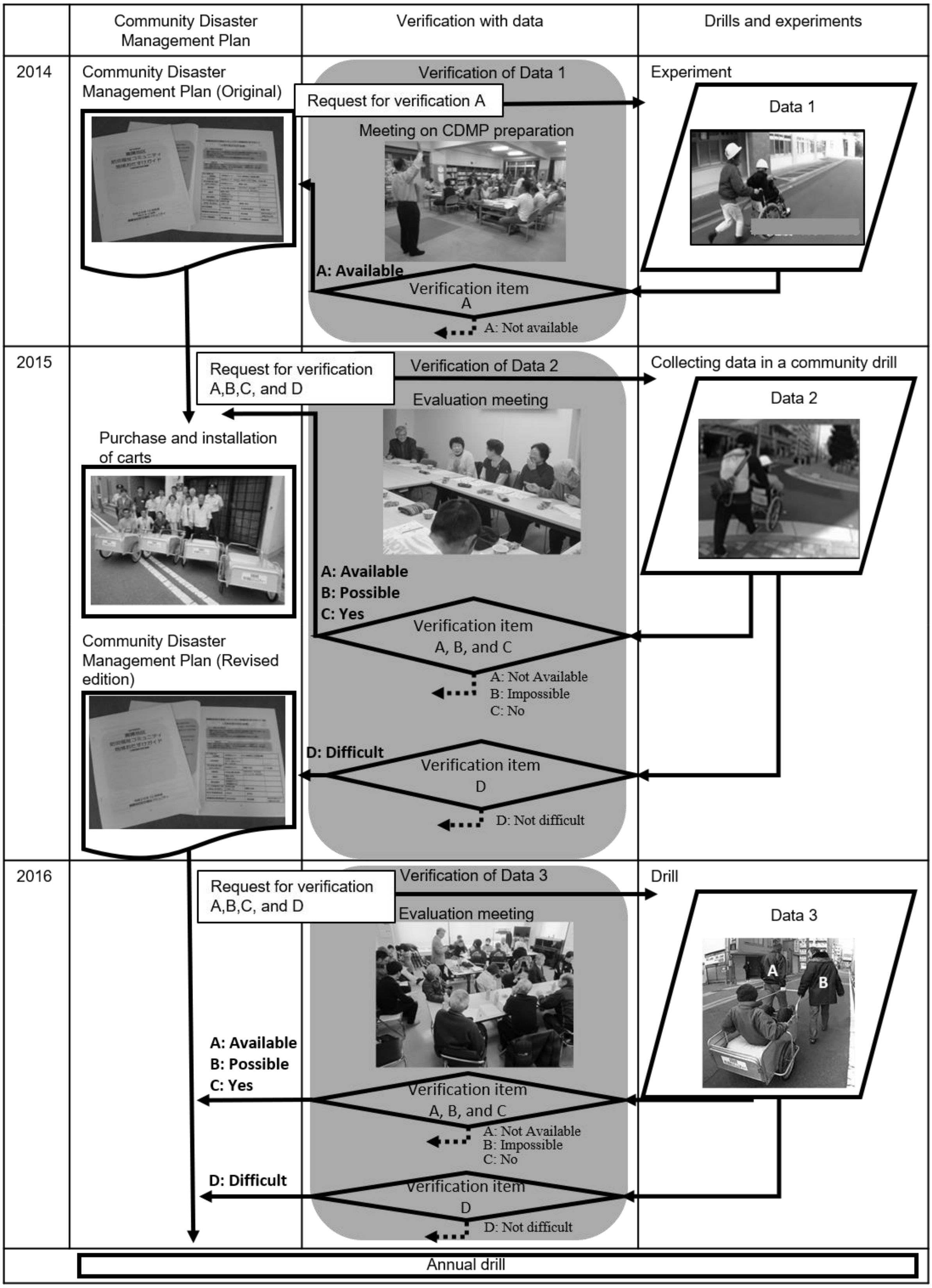

Figure 4. Verification of the plan and training. Verification items: A. Can the equipment be made available? B. Is the total evacuation time shorter than 90 min? C. Is the evacuation direction accurate? D. Is it possible to for a supporter to evacuate a second vulnerable person? Participants in each meeting judged the feasibility of each verification item.

Table 5. Items that were investigated and their results

	Verification 1	Verification 2	Verification 3	Reflection in the CDMP
Verification item A Availability of apparatus	Available	Available	Available	The support provided for the transportation of vulnerable people who use wheelchairs, transport chairs, rollators, and carts is described.
Verification item B Can the total evacuation time be within the risk-spreading time? Is the t value “ t hazard affect ＞ t Total Evacuation”?	–	Possible	Possible	Confirming that the evacuation of vulnerable people who participated in the training was completed within the risk-spreading time.
Verification item C Is the direction of supporters “from inside of the tsunami inundation assumption area to the outside of the area”?	–	Yes	Yes	Describing “If there are residents who try to return to the seaside, we should call them to inform them to remain on the mountain side from the JR line.”
Verification item D Second support	–	Difficult	Difficult	

Specifically, in the first CDMP preparation meeting, held in August 2014, the inclusion of transportation support using wheelchairs and rollators in the CDMP was discussed. In the following paragraphs, we present the outline of our experiments conducted in December 2014 (Ohtsu et al. 2016). We conducted the transportation experiment on an experimental course at Kobe University. The average speeds of a wheelchair, transport chair, and rollator were observed to be 1.87, 1.58, and 1.18 m/s, respectively. Results revealed that the abovementioned vehicles could be used for transportation during evacuation. Table 6 shows the average speed for each vehicle.

Based on these results, we confirmed that the guideline, “transportation support for vulnerable people is conducted using apparatuses with wheels, such as wheelchairs and rollators,” should be included in the CDMP. The CDMP for Shinyo District was completed in December 2014.

Table 6. Average velocity of each vehicle.

Instrument	**Rollator**	**Transport chair**	**Wheelchair**
Distance(m)	1000	1000	1000
Average velocity(m/s)	1.18	1.58	1.87

(Based on Ohtsu et al. 2016)

4.2 Verification 2

The transportation speed data for vulnerable people using three types of vehicles by residents, and the evacuation time data in an actual urban area, which were obtained in the evacuation drill (refer to entry No.2 in Tables 4 and 7 and to Figure 5) conducted by the voluntary disaster prevention organization are collectively referred to as Data 2 in this study.

With the verification of Data 2 and the knowledge of the evacuation speed and evacuation time in an actual urban area, it can be judged whether incorporating the use of the abovementioned vehicles in the CDMP is appropriate. Furthermore, Data 2 becomes a criterion for determining whether the next vulnerable person can be rescued. Verification of Data 2 was conducted at the post-training evaluation meeting.

We conducted evacuation transport training using three types of vehicles in Shinyo District and measured their respective transportation times. Using all three vehicles, transportation was completed within the risk-spreading time. Additionally, we confirmed that evacuation transport is possible in a community using the abovementioned vehicles. Supporters outside the tsunami inundation assumption area did not enter the inundated area, which would have been opposite to the evacuation movement. Furthermore, providing transportation support to a second vulnerable person was revealed to be difficult because of time limitations.

At the stage described in Section 4.1, a problem was observed: was the evacuation complete if the training for the community residents was conducted along the actual evacuation route (place)? Accordingly, we conducted evacuation training wherein the evacuation speed on the experimental course was verified in the actual community.

During the evaluation meeting post training in 2015, the average transportation speeds were reported to be 1.50, 1.42, and 1.03 m/s for the wheelchair, transport chair, and rollator, respectively (Table 7). Thus, the evacuation of all of the participants in this training (vulnerable people: 5, supporting people: 6) could be completed before the tsunami arrival time (Ohtsu and Hokugo 2017). Figure 5 shows an evacuation diagram in this training that shows the estimated tsunami first wave superimposed on a diagram that shows the distance to the evacuation site and the passage of time. The estimated first tsunami wave (b) in the figure does not intersect with the movement line of any subjects (a), indicating that evacuation was completed in this training before the arrival of the tsunami.

Table 7. Evacuation velocity, time, and distance.

Instrument	**Rollator**		**Transport chair**		**Wheelchair**		**Cart**		
Subject number	①	②	③	④	⑤	⑥	⑦	⑧	⑨
Distance(m)	952.0	1400.5	976.0	1202.4	1582.4	1165.4	1119.8	1049.3	1207.9
Evacuation time	18m04s	27m58s	11m46s	17m28s	19m35s	16m15s	18m55s	21m20s	15m17s
Average velocity except stop(m/s)*	1.15	1.08	1.47	1.36	1.43	1.55	1.26	1.23	1.40
Total average velocity(m/s)	0.88	0.83	1.38	1.15	1.35	1.20	0.99	0.82	1.32
Boarding average velocity(m/s)	1.03		1.42		1.50		1.27		

*Average velocity of empty vehicles and occupied vehicles over entire evacuation route

(Based on Ohtsu and Hokugo 2017)

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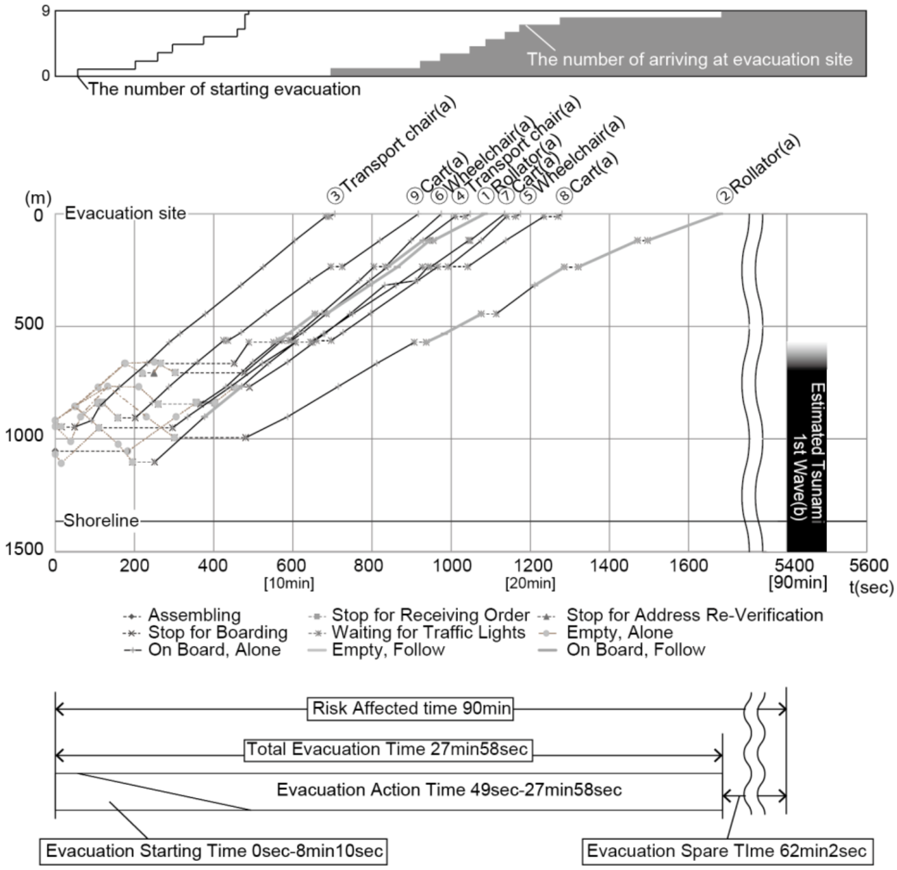

Figure 5. Evacuation diagram (Source: Ohtsu and Hokugo 2017).

Simultaneously, it was also established that, after transporting a vulnerable person, the supporter should not re-enter the assumed tsunami inundation area because a second evacuation could not be completed within 90 min, which is the interval between an earthquake and the arrival of the tsunami. Therefore, we confirmed that the transportation support should be limited to a single evacuation. Thus, the importance of the role of a "time-keeper group" (note 3) that stops a person from attempting to return to the seaside for a second attempt at providing support was reconfirmed.

In the evaluation meeting, an opinion was put forward that claimed "vulnerable people who can maintain a sitting position should be transported using a wheelchair. However, it is difficult to transport those who cannot sit in a chair, such as the elderly or disabled people, or those who are injured in the earthquake. To transport these people quickly, we need equipment such as carts, in addition to wheelchairs, and rollators."

4.3 Verification 3

The data on transportation speed and evacuation time for vulnerable people by cart, which was measured in the evacuation training conducted in 2016 (refer to entry No.3 in Tables 4 and 7 and to Figure 5), are collectively referred to as Data 3 in this study.

By verifying Data 3 and knowing the evacuation speed and evacuation time in an actual urban area, it is possible to judge whether incorporating the use of the transport vehicles in the evacuation plan is appropriate. Furthermore, Data 3 becomes a criterion for determining whether the next vulnerable person can be rescued. Verification of Data 3 was conducted at the evaluation meeting after training.

In the CDMP, the description stating that "a cart is used as an apparatus to transport vulnerable people" was added. In the evacuation training during the subsequent fiscal year, we verified the evacuation time when using a cart. We confirmed that evacuation using a cart can be completed before the arrival of a tsunami, and no movement of supporters from outside the assumed tsunami inundation area to the inside was required. Furthermore, we confirmed transportation support could not be provided for a second vulnerable person when using a cart.

Based on the opinion described in Section 4.3, the Shinyo Community bought four carts using a subsidy provided by the Kobe City Fire Bureau on June 16, 2015. Three of the carts were stored at a cooperative company in the community. The Bokomi and the cooperative companies signed an agreement according to which the executives and employees of the company became supporters who would transport vulnerable people during tsunami evacuation. The Shinyo Community added the details of this agreement to the CDMP in December 2015. Thus, verifying the feasibility of transportation using a cart became necessary. Therefore, we used carts to conduct evacuation transport training in the community on January 17, 2016 and verified the availability of carts (Ohtsu and Hokugo 2017). The employees of the cooperative companies actively participated in this training. The evacuation time, evacuation speed, and evacuation diagram obtained in the training are shown in Table 7 and Figure 5.

Since then, the Shinyo Community has been conducting evacuation training in January every year. If necessary, we intend to modify the contents of the CDMP.

5. DISCUSSION

In the present study, we dealt with tsunami evacuation training in the Shinyo District, Nagata Ward, Kobe City, based on the CDMP and examples for reconsidering the training based on the obtained results.

5.1 Summary of results

We used training to verify the effectiveness of the evacuation plan in Shinyo District. The following results were obtained, which were reflected in the subsequent plan.

A. Four types of vehicles (wheelchairs, transport chairs, rollators, and carts) can be used for transporting vulnerable people.
B. The total evacuation time was within the risk-spreading time.
C. While supporting vulnerable people, supporters did not move in the direction opposite to that of the evacuation, i.e., from outside the assumed tsunami inundation area to inside the area.
D. After transporting the first vulnerable person to the evacuation location, the supporter could not return to the assumed tsunami inundation area to transport a second vulnerable person because of time limitations.

E. Based on the verifications performed using the obtained data, the effectiveness of the CDMP was confirmed.

5.2 Uncertainties of the present study and future subjects

To use the present results for disaster responses, the following points can be cited as uncertainties that need to be overcome in the future.

Throughout the current research, we verified the effectiveness of the evacuation plan through training sessions and experiments. However, verifying whether a plan is applicable to real disasters is difficult. Although we attempted to simulate training conditions that were as close as possible to real disasters, the following uncertainties still remain.

First, with regard to human uncertainty, a time difference was observed between the training time and real evacuation. This difference stemmed from the difference in age and physical strength between the subjects who participated in the training/experiments and real supporters during a real disaster.

A supporter could possibly become a vulnerable person because of an injury. There is a risk that the designated supporters may not always be available when they are needed; for example, the supporter could be absent because of business or travel reasons. Additionally, we have to recognize that the number of employees who can operate carts and act as supporters decreases at night and on holidays, which could disrupt the flow of the evacuation plan.

Subsequently, with regard to the geographical uncertainty related to the selection of the evacuation route, it may become difficult to cross National Route No. 2 with five lanes in one direction (10 lanes in total). This is because the traffic signals may not be functioning owing to blackouts. Furthermore, the evacuation route may be blocked because of the collapse of houses/walls or damage to road surfaces. In addition, in case of an actual disaster, unexpected obstacles and failures may occur, unlike planned evacuation.

With regard to a situation in which both human and geographical uncertainties are combined, the rate of evacuation could stall. Furthermore, the evacuation speed may reduce depending on the density of pedestrian traffic passing through the railway viaduct. We should consider whether the preceding evacuees will hinder subsequent evacuees if their progress stalls.

5.3 Comparison with previous studies

Murakami et al. (2013) surveyed 324 cases of evacuation behavior from a tsunami including their travel means in the Yuriage community, Miyagi Prefecture, Japan, after the Great East Japan Earthquake, 2011. They distributed 1,135 questionnaires, collecting feedback from 324 household (response rate: 29%). For future work, we must consider using questionnaires to understand the relation between risk perception and evacuation behavior of citizens.

According to Tsuchiya et al. (2002), the speed of a person who operates a wheelchair by himself/herself is ~0.8 m/s. However, the speed that was considered in the present study is that of a vulnerable person in a wheelchair pushed by a supporter. In case of real evacuation from a tsunami, both self-operating and supported wheelchair movements may be involved. Therefore, the speed of a self-operating wheelchair will be included in future works.

The present methods, "reflecting the data in the next plan" and "verifying the plan by the data," can also be applied to other districts that plan to prepare or complete a CDMP. Finally, we believe that our study mitigates damage to human life caused by tsunami disasters, thereby making a considerable scientific contribution. In our previous research, the training and experimental data were not reflected in the plan. Therefore, this research is an improvement over our previous study in that it makes the evacuation plan more effective and practical for the considered region.

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Note 1: Bokomi

Organizations for community-based disaster risk reduction, which are led by the citizens and supported by the Kobe City Fire Bureau.

A voluntary disaster prevention organization aiming to provide assistance was found in the Kobe City in 1996 following the Great Hanshin-Awaji Earthquake of 1995. There are 191 Bokomis in the city, and the activity range of a Bokomi is within the district community of an elementary school with a population of several thousand to ten thousand people each. At times, it is written as "Bokomi," whereas it is translated at times as "Kobe city disaster-safe welfare community."

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Note 2: Tsunami height

Tsunami height is different from inundation depth. The tsunami height is the difference between the normal tide level and the height the sea level rises owing to the tsunami. Inundation depth is the height from the ground to the mark of the tsunami. In the community disaster prevention plan created by the Shinyo Community, the degree of risk does not differ depending on the inundation depth. In the tsunami inundation area, evacuating uniformly is necessary to avoid human damage.

Note 3: Time-Keeper Group

In the 2nd meeting on CDMP preparation, there was a discussion with regard to whether a supporter who finished transporting one vulnerable person to the evacuation location should return to the assumed tsunami inundation area to transport a second vulnerable person. During the 2011 Great East Japan Earthquake Disaster, more than 200 volunteer fire corps members and district welfare commissioners who assisted the evacuation of vulnerable people were killed. Therefore, it was decided that a supporter should not attempt to transport vulnerable people twice because it was dangerous. To avoid such dangers, CDMP stated that the residents who finished evacuation should play the role of a "time-keeper group" to stop the supporters from returning to the assumed tsunami inundation area.

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Original paper

Improving Flood Forecasting in Karnali River Basin of Nepal Using Rainfall-Runoff Model and Complementary Error Model

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Abstract Accuracy of flood forecast is important to take appropriate preparedness measures for saving lives and livelihoods of people residing in the floodplains. Predictions from flood forecasting models are usually uncertain which can be improved by complementing the hydrological model with an error model that can capture the information which the operational hydrological model lacks. This paper presents the application of this approach for improving daily flow forecasts for flood warning in Karnali River Basin of Nepal. A conceptual rainfall-runoff model, TUWmodel has been developed to model the rainfall-runoff processes and to predict the runoff at the outlet of the basin at Chisapani. The model has been calibrated for the period 2008-2011 with Nash-Sutcliffe Efficiency (NSE) 0.91 and percent bias (PBIAS) -0.7% and validated for the period 2012-2014 with NSE 0.88 and PBIAS -9.1% using observed temperature, precipitation and discharge data. A complementary ARIMA error model was developed from the error series for calibration set using automatic procedure and the predicted discharges were corrected using the error predictions from the error model. After error corrections, NSE and PBIAS were 0.95 and 0.1% respectively for calibration and 0.92 and 0.1% respectively for validation indicating significant improvements in the skill of forecasts.

Key words: Flood forecasting, error modeling, flood warning, hydrological model, ARIMA

1. INTRODUCTION

Hydrological models are important component of a flood forecasting system for estimating future flood discharge and assess the extent of inundation (Grange et al., 2015). Hydrologists have

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used various types of hydrological models which can be classified based on process description, spatial representation or aspect of randomness (Todini, 2007). Based on process description, the models can be classified as physically based, conceptual and empirical data-driven models.

Lumped conceptual hydrologic models are the most common in research and used for operational flood forecasting (WMO, 2011). These models are based upon simple conceptual representation of the hydrologic cycle in the catchment with a structure of interconnected storages that represent overland flow, interflow and baseflow. Customization of such models involves estimating the model parameters by calibration with observed hydrologic data such as river level or discharge. The operational application of such model depends upon their capacity to reproduce observed hydrologic behavior of the catchment such as the rainfall–runoff processes. Examples of such models are NAM model (DHI, 2011), HBV model (Bergstörm, 1976), Soil Conservation Services (SCS) Curve Number method (Maidment, 1993), LCM model (Li and Liu, 2017), TANK model (Sugawara, 1995), SACRAMENTO model (Burnash, 1995), ARNO model (Todini, 1996) and the XINANJIANG model (Zhao et al,1980).

Amongst the various hydrologic processes, information on flood peak and time to the peaks, are important to take appropriate preparedness measures to save lives and livelihood assets. The flood peak information is used as input to the hydraulic model to estimate flood depth and discharge at various locations along the channel reach and floodplain (DHI, 2011, Pingping et al, 2018). Application of hydrologic models for flood forecasting is usually constrained by different sources of uncertainty such as inadequacy in model structure, incorrect model parameters, unreliable meteorological forecast or erroneous data (Grange et al., 2015). Consequently, the models fail to reproduce the observed hydrologic processes, hydrographs and flood peaks, and the inability to predict future floods accurately might have negative consequences in informing relevant stakeholders who make decisions based upon forecasts. Estimation of future flood peaks involves estimating the actual initial state of the basin, forecasting the inputs, and describing the different hydrologic processes that might provide an increased lead time. Ultimately, the quality of flood forecasts depends upon the accuracy and methodology applied whilst implementing each of these aforementioned aspects.

A data-driven time series model can be employed to enhance the prediction of floods by a conceptual model. Here, a calibrated conceptual model acts as the basic model that approximately captures the dominant hydrologic processes and forecasts the behavior of the catchment, results of which are deterministic in nature (Grange et al., 2015). A time series model can then be formulated on the errors. By analysing the error series, important information not captured by the conceptual model can be extracted which can be used for improving the prediction skill of a conceptual model. In this study, we used this technique for enhancing the performance of TUWmodel for flood forecasting in the Karnali River, Western Nepal.

Data-driven models based on the errors from a conceptual model can reveal whether the conceptual model is adequate to identify essential relationships between the input–output data series (Kachroo, 1992). Data-driven error models can capture the persistency in the time series, which the conceptual model is unable to capture. Thus, the data-driven models can complement the conceptual model to improve the output (Serban and Askew, 1991).

Many researchers have demonstrated the application of data-driven model to improve the accuracy of conceptual models. Gragne et al. (2015) have applied complementary error modeling framework to improve real-time inflow forecasting into hydropower reservoirs in Norway by utilizing HBV model. Likewise, Morawietz et al. (2011) have evaluated different versions of autoregressive error models as post-processors for probabilistic streamflow forecasts. Similarly, Abebe and Price (2003) have applied artificial neural network model to improve the predictions of the conceptual rainfall-runoff model for the Sieve Basin in Italy. Liu et al. (2012) have also provided a comprehensive review of the data assimilation and error modeling in hydrologic forecasting.

The novelty of this research is that differs from the past work on the automatic estimation of parameters from the conceptual rainfall-runoff model, data-based ARIMA error model and Box-Cox transformation. Gragne et al. (2015) used already calibrated HBV model and the parameters of error model have been estimated by least squares method using an iterative algorithm. We applied Differential evolution (DE) global optimization algorithm available in R package **DEoptim** to automatically calibrate the model parameters. The parameters of error model and Box-Cox transformation have also been estimated automatically using R package '**forecast**'. The automatic procedure facilitates the application of this approach in real-time flood forecasting in an effective and efficient way.

The bias, persistence and heteroscedasticity present in the errors reflect structural inadequacy of the conceptual model to capture the complete catchment processes and, hence, are critical in defining the structure of the data-based error model. Here, we describe the errors in a transformed space with Box-Cox transformation (Box and Cox, 1964) and estimate the data-driven error model and the transformation parameters with an automatic procedure using R package '**forecast**' (See https://CRAN.R-project.org/package=forecast).

In the next section, we describe how the conceptual rainfall-runoff model and complementary error models are set-up. An example application in the Karnali River, Western Nepal is presented in the subsequent section which includes description of the study area, data used, findings from the evaluation of the complimentary error model and its application during calibration and validation, and results of forecasting capabilities.

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2. STUDY AREA AND DATA

The Karnali is a perennial, trans-boundary river that originates from Tibet, crosses the dissected hill slopes of Western Nepal and flows into India. Tributaries of Karnali are the snow-fed rivers such as Mugu Karnali and Humla Karnali (Figure 1). The West Seti River (202 km) and the Bheri River (264 km) are the other major tributaries of the Karnali. It enters the lowlands of the Terai plains via a spectacular gorge at the town of Chisapani, where its catchment area is 45,583 km^2. The Karnali then remarkably divides into two main channels, Geruwa on the left and Kauriala on the right few kilometers downstream of Chisapani.

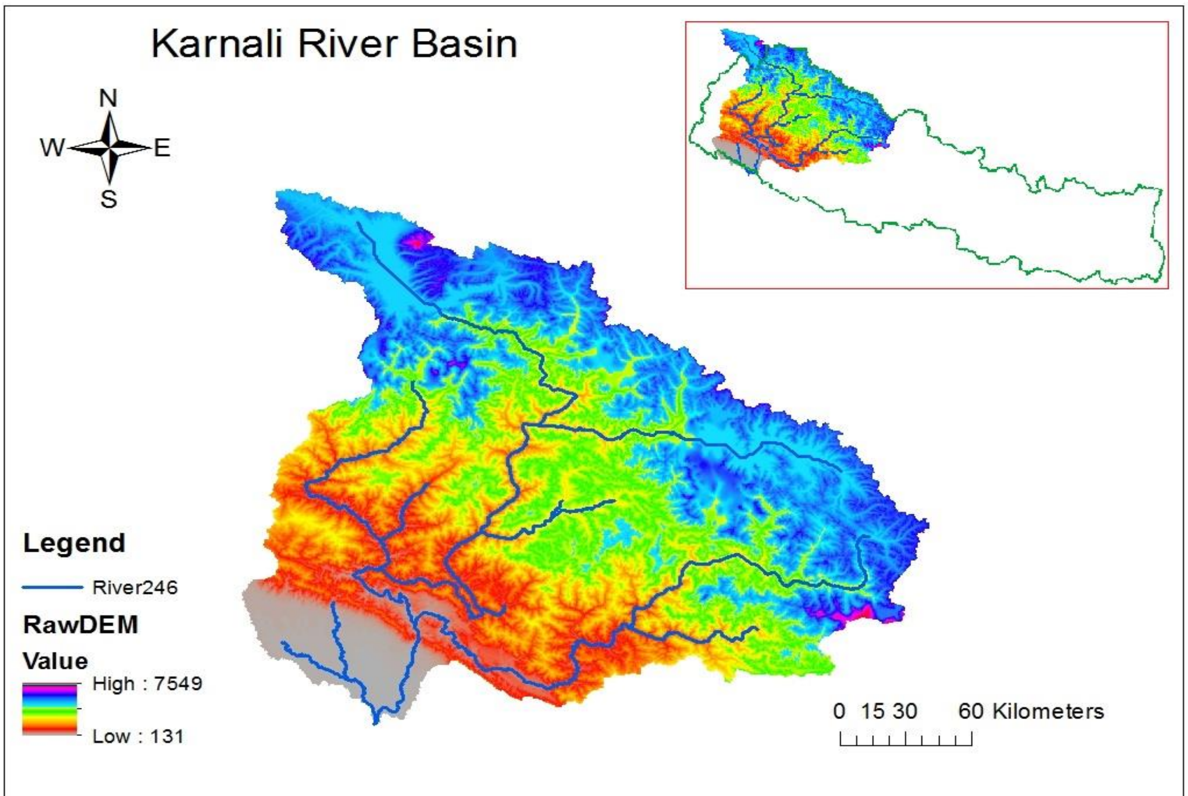

Figure 1. Karnali River Basin

The Terai plain downstream of Karnali is fertile and most of the alluvial plains are devoted to agriculture. In recent years, the development activities have increased with the construction of roads, irrigation, flood control embankments, electricity and telecommunication infrastructures downstream of Chisapani in the Terai belt. Many people reside alongside the floodplains because of the economic opportunities which have inadvertently increased vulnerabilities due to flooding. Intense monsoon rainfall that triggers the floods turns into disaster because of high number of communities residing along the floodplains within the close proximity of the river. For example, the Karnali floods in 15 August, 2014 affected 173,800 people with 29,680 people displaced and 53 people killed. More than 1,240 houses were destroyed and 435 houses damaged.

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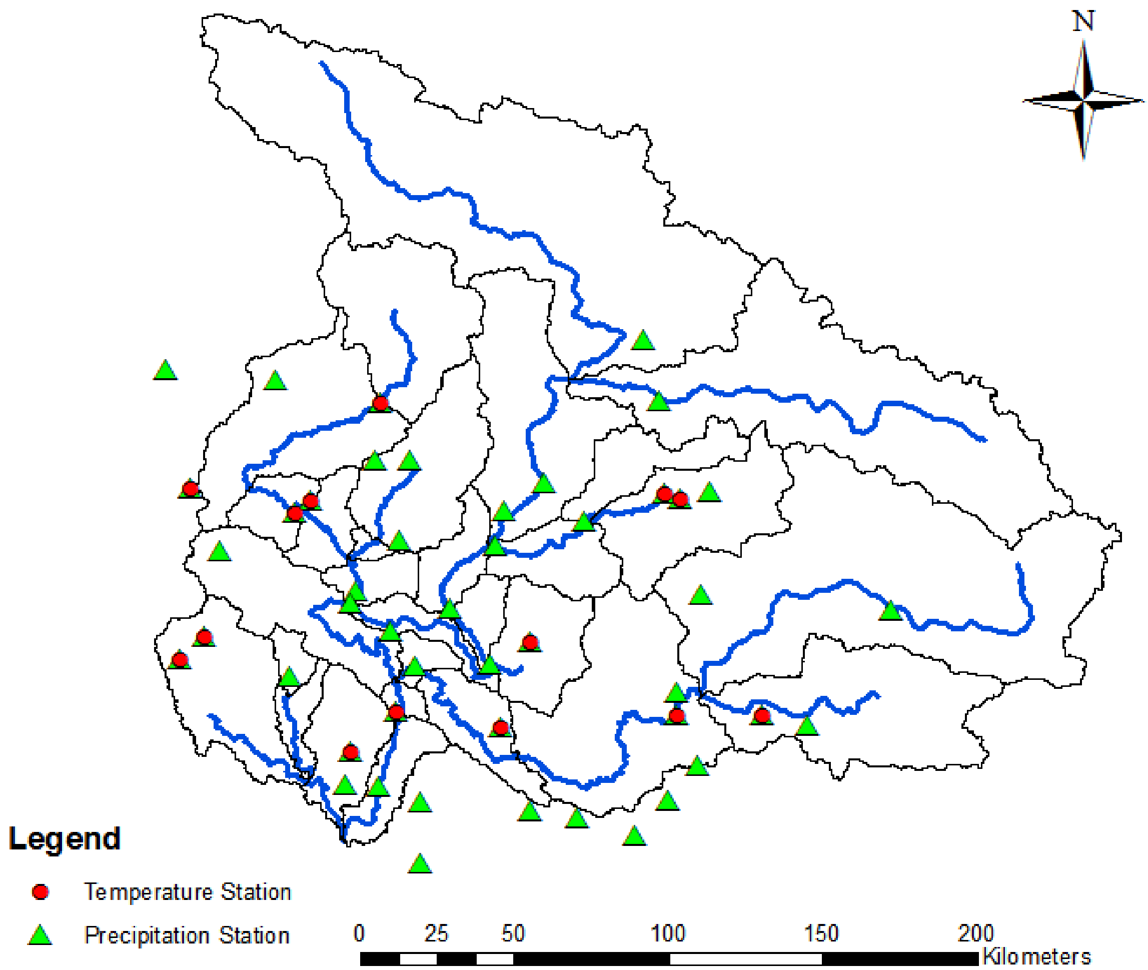

Figure 2. Precipitation and temperature stations

For this research, we used the observed discharge data of Chisapani station for 7 years (01/01/2008-31/12/2014) obtained from the Department of Hydrology and Meteorology of Nepal. Similarly, observed daily precipitation data of 47 stations and daily air temperature data of 14 stations have also been obtained for the same period. In the operational forecasting mode, the air temperature and precipitation input over the forecast lead time will be obtained from the Numerical Weather Prediction (NWP) model run by Meteorological Forecasting Division of the Department of Hydrology and Meteorology of Nepal (http://mfd.gov.np/nwp/). As this study aims to improve hydrologic forecasts for flood forecasting by complementing the conceptual model by an error model, we assume that the predictions from the TUWmodel are made using the best possible input data. Hence, the observed air temperature and precipitation data are used for flood forecasts in hindcast mode. In operational setting with NWP forecast, the error model needs to be recalibrated. The basin average precipitation and temperature were computed by Thiessen polygon method and arithmetic average method respectively. Figure 2 depicts the location of precipitation and temperature stations whereas basin average precipitation, temperature and maximum daily discharge at Chisapani for the period 2008-01-01 to 2014-12-31 are presented in Figure 3.

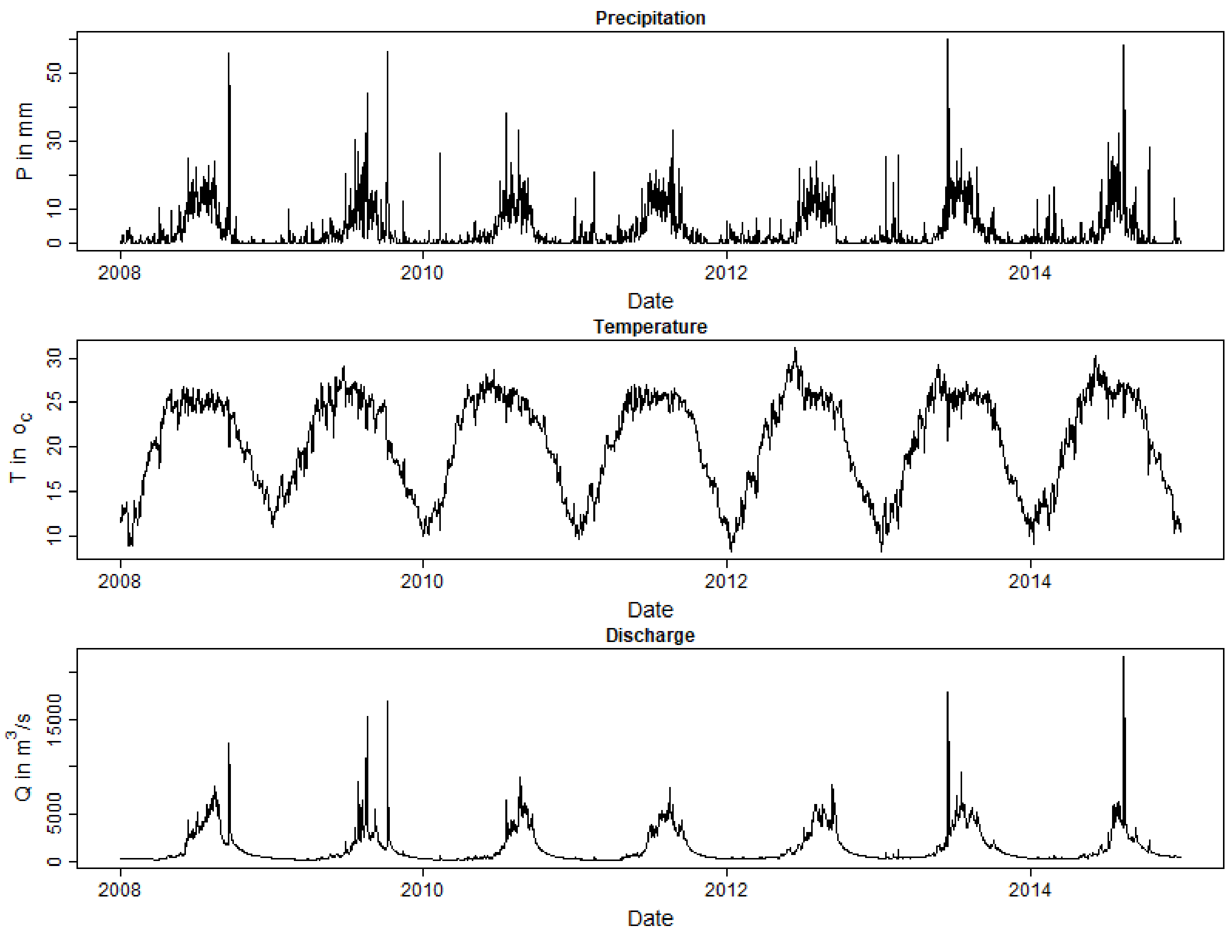

Figure 3. Basin average precipitation, temperature and maximum daily discharge at Chisapani

The modified Blaney-Criddle formula is one of the simplest methods for calculating reference evapotranspiration (Blaney and Criddle, 1950) which requires only mean daily temperature data. The original Blaney-Criddle formula is given by:

$$ET = p.(0.46.T + 8) \tag{1}$$

The modified Blaney-Criddle formula is as follows:

$$ET = -1.55 + 0.96\,p.(0.457.T + 8.128) \tag{2}$$

Where, ET = Reference evapotranspiration (mm/day)

T = mean daily temperature (°C)

p = mean daily percentage of annual daytime hours (it is function of latitude)

The mean daily percentage of annual daytime hours for 25-30 degree north latitude is given in Table 1. TUWmodel requires potential evapotranspiration as input which is calculated by modified Blaney-Criddle method using mean daily temperature data for the Karnali. R Codes have been written for this purpose.

Table 1. Mean daily percentage of annual daytime hours for 25-30 degree north latitude

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
p	0.24	0.255	0.27	0.29	0.305	0.315	0.31	0.295	0.28	0.26	0.245	0.235

The observed data were divided into calibration and validation set. Calibration and validation periods have been specified from 01/01/2008 to 31/12/2011 and 01/01/2012 to 31/12/2014 respectively. Both calibration and validation data set consisted of several flood peaks. There have been major flood events with the water level crossing the danger level in 2008, 2009, 2013 and 2014. The validation set consisted of the historically record flood peak on August 2014 with the recurrence interval of 1 in 100 years.

3. METHODOLOGY

3.1 Conceptual Rainfall-Runoff Model

Here, we have selected a lumped conceptual rainfall-runoff model **TUWmodel** for this research. **TUWmodel** follows the structure of the HBV (Hydrologiska Byråns Vattenbalansavdelning) model which runs on a daily or shorter time step and consists of a snow routine, a soil moisture routine and a flow routing routine (See Parajka, Merz and Bloeschl, 2007, Merz and Bloeschl, 2004). **Snow Routine**:

The snow routine represents snow accumulation and melt by a simple degree-day concept, using a degree-day factor DDF and a melt temperature parameter Tm. The catch deficit of precipitation gauges during snowfall is corrected by a snow correction factor SCF. A threshold temperature interval Tr – Ts is used to distinguish between rainfall, snowfall and a mix of rain and snow. Mean daily precipitation P in an elevation zone is partitioned into rain P_r and snow P_s based on the mean daily air temperature T_a.

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$P_r = P$ If $T_a \geq T_r$ (3)

$P_r = P\frac{T_a - T_s}{T_r - T_s}$ If $T_s < T_a < T_r$ (4)

$P_r = 0$ If $T_a < T_s$ (5)

$P_s = P - P_r$ (6)

Where T_a is air temperature, T_s is lower threshold temperature below which precipitation is snow and T_r is upper threshold temperature above which precipitation is rain. Melt starts at temperature above a threshold T_m.

$M = (T_a - T_m)\ DDF$ If $T_a > T_m$ and $SWE > 0$ (7)

Where, M is the amount of melt water per time step, DDF is the degree-day factor and SWE is the snow water equivalent. The catch deficit of the precipitation gauges during snowfall is corrected by a snow correction factor SCF. Changes in the snow water equivalent from days i -1 to i are accounted by Equation (8) below.

$$SWE_i = SWE_{i-1} + (SCF.P_s - M)\Delta t \quad (8)$$

Where SCF is snow correction factor and Δt is the time step.

Soil Moisture Routine:

The soil moisture routine represents runoff generation and changes in the soil moisture state of the catchment and involves three parameters: the maximum soil moisture storage FC, a parameter representing the soil moisture state above which evaporation is at its potential rate, termed the limit for potential evaporation LP, and a parameter in the non-linear function relating runoff generation to the soil moisture state, termed the non-linearity parameter β.

$$S_{SM,i} = S_{SM,i-1} + P_r + M - E_a \quad (9)$$

Where, S_{SM} is the soil moisture of a top soil layer controlling runoff generation and actual evaporation E_a. The contribution ΔS_{UZ} of rain and snowmelt to runoff is calculated by an explicit scheme as a function of the soil moisture of the top layer S_{SM} using a non-linear relationship with two free parameters, FC and β:

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$$\Delta S_{UZ} = (\frac{S_{SM}}{FC})^{\beta} (P_r + M) \tag{10}$$

FC is the ma imum soil moisture storage. The parameter β controls the characteristics of runoff generation and is a non-linearity parameter. If the top soil layer is saturated, i.e. S_{SM} = FC, then all rainfall and snowmelt contribute to runoff. The actual evaporation E_a is calculated from potential evaporation E_p by a piecewise linear function of the soil moisture of the top layer:

$$E_a = E_p \frac{S_{SM}}{LP} \quad \text{If } S_{SM} < LP \tag{11}$$

$$E_a = E_p \quad \text{If } S_{SM} \geq LP \tag{12}$$

Where, LP is a parameter termed the limit for potential evapotranspiration E_p.

Flow Routing Routine:

Runoff routing on the hill slopes is represented by an upper and a lower soil reservoir S_{UZ} and S_{LZ} respectively. Excess rainfall ΔS_{UZ} enters the upper zone reservoir and leaves this reservoir through three paths: outflow from the reservoir based on a fast storage coefficient K_1; percolation to the lower zone with a constant percolation rate C_P; and, if a threshold of the storage state LS_{UZ} is exceeded, through an additional outlet based on a very fast storage coefficient K_0. Water leaves the lower zone based on a slow storage coefficient K_2. The outflow from both reservoirs Q_G is then routed by a triangular transfer function representing runoff routing in the streams.

$$B_Q = B_{MAX} - C_R Q_G \quad \text{If } (B_{MAX} - C_R Q_G) \geq 1 \tag{13}$$

$$B_Q = 1 \quad \text{Otherwise} \tag{14}$$

Where B_Q is the base of the transfer (triangular) function, B_{MAX} is the maximum base at low flows and C_R is a free scaling parameter.

The model's input data are precipitation, air temperature, potential evapotranspiration and catchment area. For this research, we used the model as a lumped model with one parameter set and input data set for the entire catchment. The model could also be used as a semi-distributed model by dividing the catchment into sub-basins. The 15 model parameters are described in Table 2 below.

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Table 2. Parameters of TUWmodel

S No.	Parameter	Description	Range	Unit
1	SCF	snow correction factor	0.9-1.5	
2	DDF	degree day factor	0.0-10.0	mm/degC/timestep
3	Tr	threshold temperature above which precipitation is rain	1.0-3.0	degC
4	Ts	threshold temperature below which precipitation is snow	-3.0-1.0	degC
5	Tm	threshold temperature above which melt starts	-2.0-2.0	degC
6	LP	parameter related to the limit for potential evaporation	0.0-1.0	
7	FC	field capacity, i.e., max soil moisture storage	0-600	mm
8	BETA	the nonlinear parameter for runoff production	0.0-20.0	
9	K0	storage coefficient for very fast response	0.0-2.0	timestep
10	K1	storage coefficient for fast response	2.0-30.0	timestep
11	K2	storage coefficient for slow response	30.0-250.0	timestep
12	LSUZ	threshold storage state, i.e., the very fast response start if exceeded	1.0-100.0	mm
13	CP	constant percolation rate	0.0-8.0	mm/timestep
14	BMAX	maximum base at low flows	0.0-30.0	timestep
15	CR	free scaling parameter	0.0-50.0	$timestep^2/mm$

Table 3 presents the model output vector. The model output consists of a vector of simulated runoff as q (mm/timestep), and 11 additional vectors.

Table 3. Model output vector

SN	Output	Description	Unit
1	q	simulated runoff	mm/timestep
2	qzones	simulated runoff for each zone	mm/timestep
3	q0	surface runoff	mm/timestep
4	q1	subsurface runoff	mm/timestep
5	q2	baseflow	mm/timestep
6	rain	liquid precipitation	mm/timestep
7	snow	solid precipitation	mm/timestep
8	melt	snowmelt	mm/timestep
9	moist	soil moisture	mm
10	swe	snow water equivalent	mm
11	suz	upper storage zone	mm
12	slz	lower storage zone	mm

The model is available freely as R library (See https://cran.r-project.org/package=TUWmodel) . Further coding is needed for processing input data, calibration and validation, forecasting and o utput generation. Codes have been written in R to customize the TUWmodel for Karnali River.

3.2 Calibration of Model Parameters

The performance of a hydrological model depends on how well its parameters are calibrated. Hence, the calibration process should be chosen carefully to maximize the performance of the model. Calibration of a hydrological model is a tedious process. A hydrological model can be calibrated using manual trial and error method, global optimization method or combination of both. For a hydrological model having many parameters, manual method can be extremely time consuming and uncertain to identify optimum parameter values. Alternatively, a global optimization algorithm can be effective and efficient. Differential evolution (DE) is a stochastic, population-based global optimization algorithm using crossover, mutation and selection operators that is effective on many problems of interest in science and technology. DE is particularly well-suited to find the global optimum of a real-valued function of real-valued parameters, and does not require that the function be either continuous or differentiable. DE has been successfully applied in a wide variety of fields, from computational physics to operations research. Detailed description and R code of differential evolution can be found on the website: http://www1.icsi.berkeley.edu/~storn/code.html.

Optimum parameters of TUWmodel were found using DE optimization algorithm (Mullen et al., 2011) which allows box constraints, that is each variable can be given a lower and/or upper bound (Byrd et al., 1995). The initial value must satisfy the constraints. We used R package DEoptim to automatically calibrate the model parameters. The DEoptim package is available at https://cran.r-project.org/web/packages/DEoptim/index.html.

3.3 The Complementary Error Model

The error model aims at exploiting the bias, persistence and heteroscedasticity in the errors and estimating the errors is likely to occur in the forecast lead time. Forecasting the error in the lead time is regarded as a two-step process that comprises of offline identification and estimation of the error model, and error predictions based on most recent information.

In this study, we aim to fit Auto Regressive Integrated Moving Average (ARIMA) model for the error series (Brockwell and Davis, 1996). First, we compute error series as the difference between observed and predicted discharge at time t expressed as $\mathrm{Y_t = Q_t - \widehat{Q}_t}$. Then the errors are analyzed to see whether these are random and stationary or show some trend and heteroscedasticity. If the series is non-stationary, then it is stationarized by differencing. This is then followed by assessment of the pattern of autocorrelation function (ACF) and partial autocorrelation function (PACF) to determine if lags of the stationarized series and/or lags of the forecast errors should be included in the forecasting equation. The autocorrelation function (ACF) plot shows the correlation of the series with itself at different lags. The partial autocorrelation function (PACF) plot shows the amount of autocorrelation at lag k that is not adequately explained by lower-order autocorrelations. The suggested error model is fitted and the error diagnostics are checked, particularly for the error ACF and PACF plots, to comprehend if all coefficients are significant and the entire pattern have been explained. Patterns that remain in the ACF and PACF may suggest the need for additional autoregressive (AR) or moving average (MA) terms.

Let *Y* denote the *original* series and *y* denote the *differenced* (stationarized) series.

No difference (d=0): $y_t = Y_t$ (15)

First difference (d=1): $y_t = Y_t - Y_{t-1}$ (16)

Second difference (d=2): $y_t = (Y_t - Y_{t-1}) - (Y_{t-1} - Y_{t-2}) = Y_t - 2Y_{t-1} + Y_{t-2}$ (17)

The AutoRegressive Integrated Moving Average (ARIMA) error forecasting equation is given by $\hat{y}_t = \mu + \emptyset_1 y_{t-1} + \cdots + \emptyset_p y_{t-p} - \theta_1 e_{t-1} - \cdots - \theta_q e_{t-q}$ (18)

Where, μ is constant term, φ and θ are parameters of autoregressive (AR) and moving average (MA) terms and p and q are order of autoregressive and moving average terms (Nau, 2014).

Positive ACF at lag 1 indicates AR series and negative ACF at lag 1 indicates MA series. For the AR series, ACF dies out gradually and PACF cuts off sharply after a few lags. For the MA series, ACF cuts off sharply after a few lags and PACF dies out more gradually (Nau, 2014).

We used R package ‘forecast’ to estimate the orders and parameters of ARIMA model automatically (See http://github.com/robjhyndman/forecast). Version 7.2 of the package was used for this study (Hyndman and Khandakar, 2008). The auto.arima function in ‘forecast’ package estimates the best fit ARIMA model to univariate time series according to either Akaike’s Information Criterion (AIC) or Bayesian Information Criteria (BIC) value.

We applied Box-Cox transformation to the error series (y) before ARIMA model is estimated (Box and Cox, 1964). A Box-Cox transformation is a way to transform non-normal dependent variables into a normal shape. The Box-Cox transformation is given by:

$$y(\lambda) = \begin{cases} \frac{y^{\lambda-1}}{\lambda}, & \lambda \neq 0 \\ logy, & \lambda = 0 \end{cases} \quad (19)$$

At the core of the Box-Cox transformation is an exponent, lambda (λ), which varies from -5 to 5. We used BoxCox.lambda function of R package ‘forecast’ to estimate the Box-Cox transformation parameter (λ) automatically by minimizing the coefficient of variation of the error series (Guerrero,1993).

3.4 Goodness-of-fit Measures

For evaluating the goodness-of-fit (GOF) measures of the model, the following 20 numerical measures are defined.

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Table 4. Goodness-of-fit measures

GOF measures	**Description**
me	Mean Error
mae	Mean Absolute Error
mse	Mean Squared Error
rmse	Root Mean Square Error
nrmse	Normalized Root Mean Square Error (-100% <= nrms <= 100%)
PBIAS	Percent Bias
RSR	Ratio of RMSE to the Standard Deviation of the Observations, RSR = rms / sd(obs). (0 <= RSR <= +Inf)
rSD	Ratio of Standard Deviations, rSD = sd(sim) / sd(obs)
NSE	Nash-Sutcliffe Efficiency (-Inf <= NSE <= 1)
mNSE	Modified Nash-Sutcliffe Efficiency
rNSE	Relative Nash-Sutcliffe Efficiency
d	Index of Agreement (0 <= d <= 1)
md	Modified Index of Agreement
rd	Relative Index of Agreement
cp	Persistence Index (0 <= PI <= 1)
r	Pearson Correlation coefficient (-1 <= r <= 1)
R2	Coefficient of Determination (0 <= R2 <= 1). Gives the proportion of the variance of one variable that is predictable from the other variable
bR2	R2 multiplied by the coefficient of the regression line between sim and obs (0 <= bR2 <= 1)
KGE	Kling-Gupta efficiency between sim and obs (0 <= KGE <= 1)
VE	Volumetric efficiency between sim and obs (-Inf <= VE <= 1)

We used the R package hydroGOF to compute the goodness-of-fit measures (https://cran.r-project.org/web/packages/hydroGOF/index.html).

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The Nash-Sutcliffe Efficiency (NSE) coefficient and Percent Bias (PBIAS) are the most important performance measures widely used to evaluate the model performance. The NSE and PBIAS can be defined respectively as follows:

$$NSE = 1 - \frac{\sum_{t=1}^{N}(Q_t^{pred} - Q_t^{obs})^2}{\sum_{t=1}^{N}(Q_t^{obs} - Q^{mean})^2} \tag{20}$$

$$PBIAS = \frac{\sum_{t=1}^{N}(Q_t^{pred} - Q_t^{obs})}{\sum_{t=1}^{N}Q_t^{obs}} \times 100 \tag{21}$$

Where Q_t^{pred} is predicted flow, Q_t^{obs} is observed flow and Q^{mean} is the mean observed flow.

PBIAS measures the tendency of the predicted flows to be larger or smaller than the observed flows. Hence, it gives a measure of mass conservation. The optimal value is 0.0, whereas positive value indicates a tendency of model overestimation and negative value indicates a tendency of model underestimation.

The Nash-Sutcliffe Efficiency coefficient (NSE) measures the fraction of the variance of the observed flows explained by the model in terms of the relative magnitude of the residual variance (noise) to the variance of the flows (information). It can range from $-\infty$ to 1. An efficiency of 1 (NSE = 1) corresponds to a perfect match of modeled discharge to the observed data. An efficiency of 0 (NSE = 0) indicates that the model predictions are as accurate as the mean of the observed data, whereas an efficiency less than zero (NSE < 0) occurs when the observed mean is a better predictor than the model or, in other words, when the residual variance is larger than the data variance. Essentially, the closer the model efficiency is to 1, the more accurate the model is. In general, the model simulation can be judged as satisfactory if NSE > 0.5 and PBIAS ±25% for streamflow (Moriasi et al, 2007).

Additionally, the time series plots of observed and simulated hydrograph and scatterplots are also compared. Visual inspection of simple hydrograph plots that compare the predictions to actual measurements in calibration and validation set can provide significant information about how much the predictions are close to the observations for different flow regimes.

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4. RESULTS

The differential evolution optimization algorithm as described above was used for automatic calibration of 15 parameters of TUWmodel. The mean square error was defined as the objective function to minimize. The objective function converged after 356 iterations. Figure 4 below shows the objective function plot.

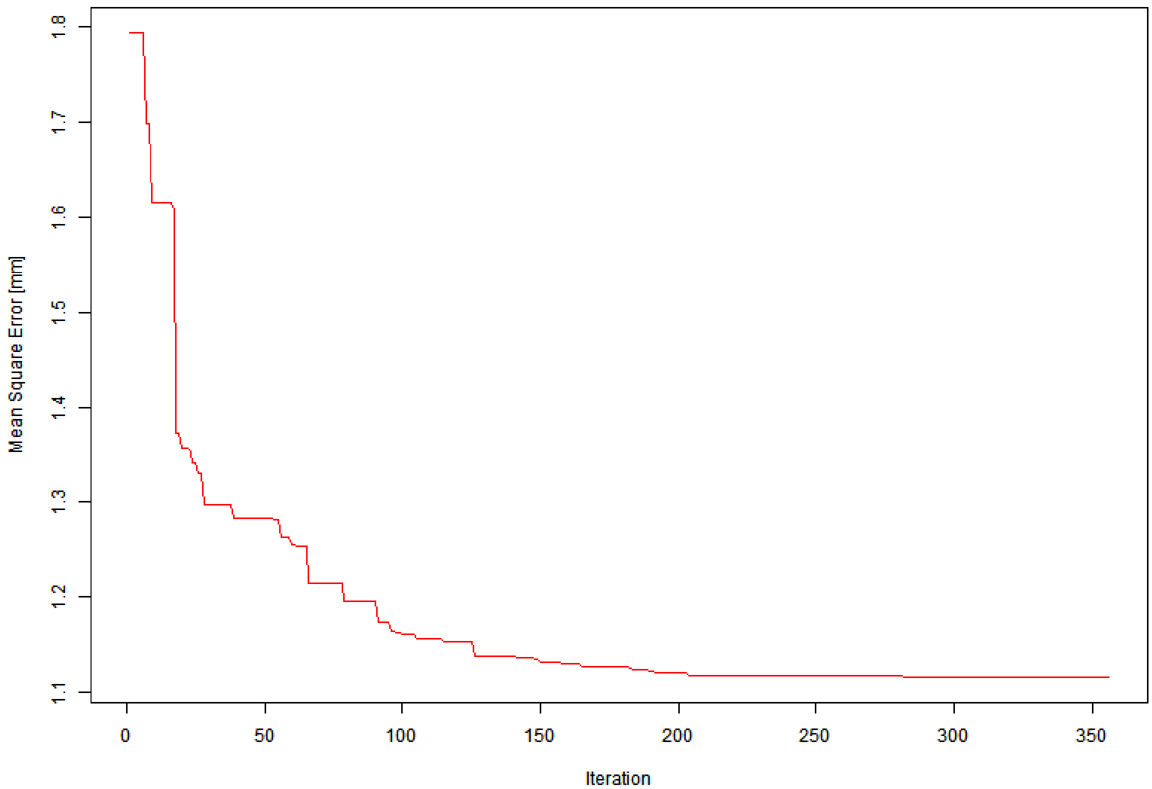

Figure 4. Objective function plot

The set of optimal parameter values obtained by automatic calibration are presented in Table 5 below.

Table 5. Optimal parameter values for calibration set

S No.	Parameter	Description	Range	Optimal value	Unit
1	SCF	snow correction factor	0.9-1.5	1.19	
2	DDF	degree day factor	0.0-10.0	3.35	mm/degC/ timestep
3	Tr	threshold temperature above which precipitation is rain	1.0-3.0	2.94	degC
4	Ts	threshold temperature below which precipitation is snow	-3.0-1.0	-2.49	degC
5	Tm	threshold temperature above which melt starts	-2.0-2.0	1.08	degC
6	LP	parameter related to the limit for potential evaporation	0.0-1.0	1	
7	FC	field capacity, i.e., max soil moisture storage	0-600	288.34	mm
8	BETA	the nonlinear parameter for runoff production	0.0-20.0	0.38	
9	K0	storage coefficient for very fast response	0.0-2.0	1	timestep
10	K1	storage coefficient for fast response	2.0-30.0	2.72	timestep
11	K2	storage coefficient for slow response	30.0-250.0	30	timestep
12	LSUZ	threshold storage state, i.e., the very fast response start if exceeded	1.0-100.0	32.83	mm
13	CP	constant percolation rate	0.0-8.0	5.01	mm/timestep
14	BMAX	maximum base at low flows	0.0-30.0	4.88	timestep
15	CR	free scaling parameter	0.0-50.0	32.81	timestep^2/mm

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Figures 5 and 6 present the time series plot and scatterplot of observed and simulated flows at Chisapani station for calibration periods. The joint hydrograph of observed and simulated flows shows that the model is able to produce flow pattern nicely but it underestimates the peak flows. Figures 7 and 8 present the time series plot and scatterplot of observed and simulated flows at Chisapani station for validation periods. The model is able to produce flow pattern nicely but it underestimates the peak flows for the validation data set also. The performance of TUWmodel model was similar for calibration and validation period.

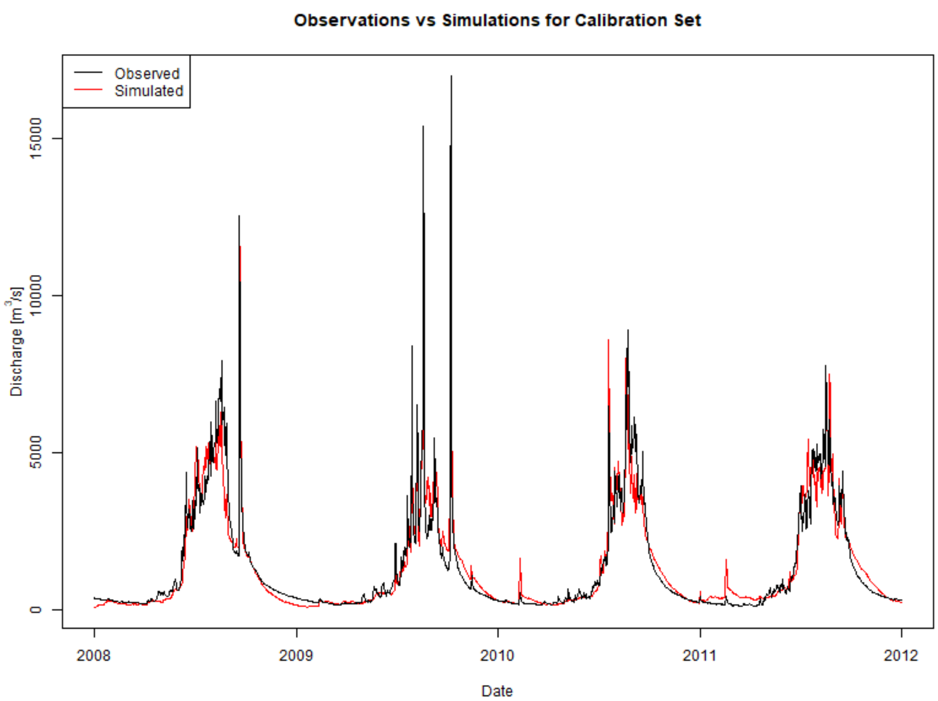

Figure 5. Time series plot for calibration set

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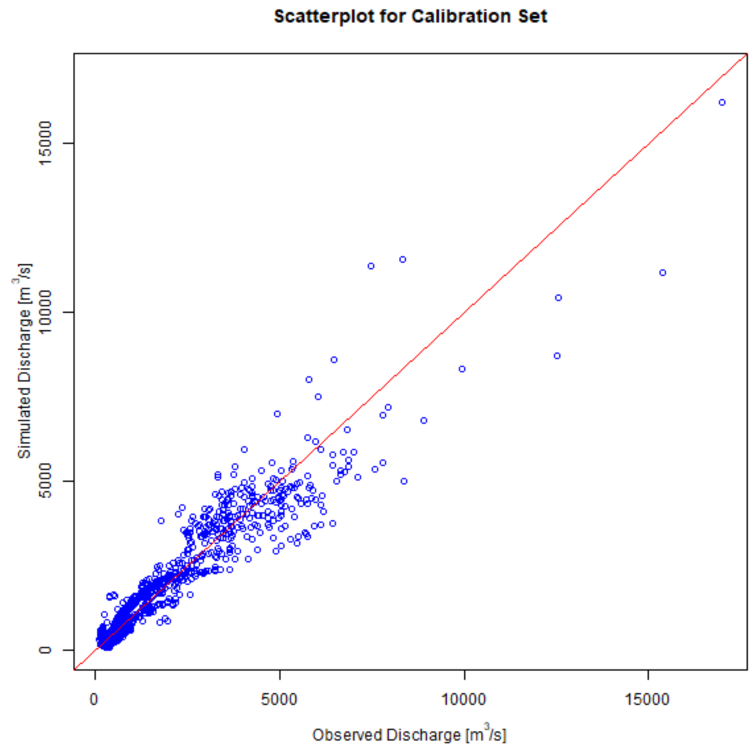

Figure 6. Scatterplot for calibration set

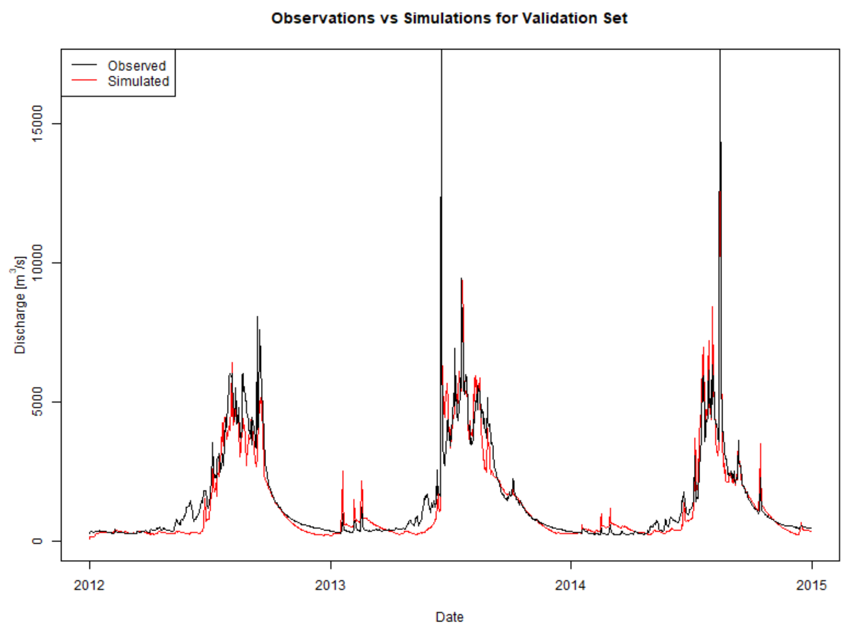

Figure 7. Time series plot for validation set

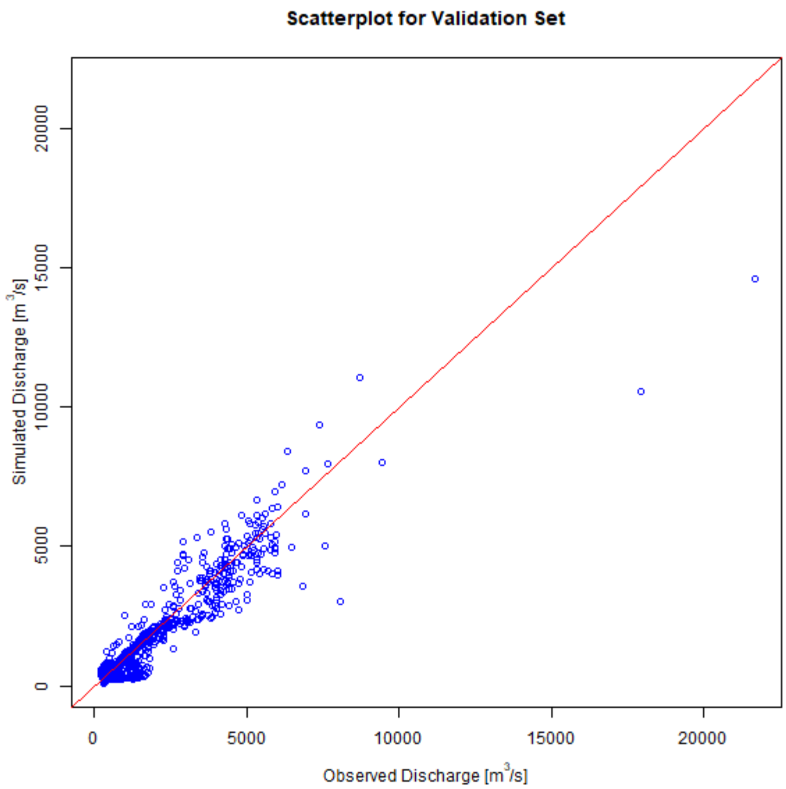

Figure 8. Scatterplot for validation set

The autocorrelation function (ACF) and partial autocorrelation function (PACF) of the error series have been analyzed. The error plot in Figure 9 shows the variability of errors. The error variations are high for high flows. The ACF and PACF plots in Figure 9 indicate the high degree of persistency and presence of both AR and MA terms.

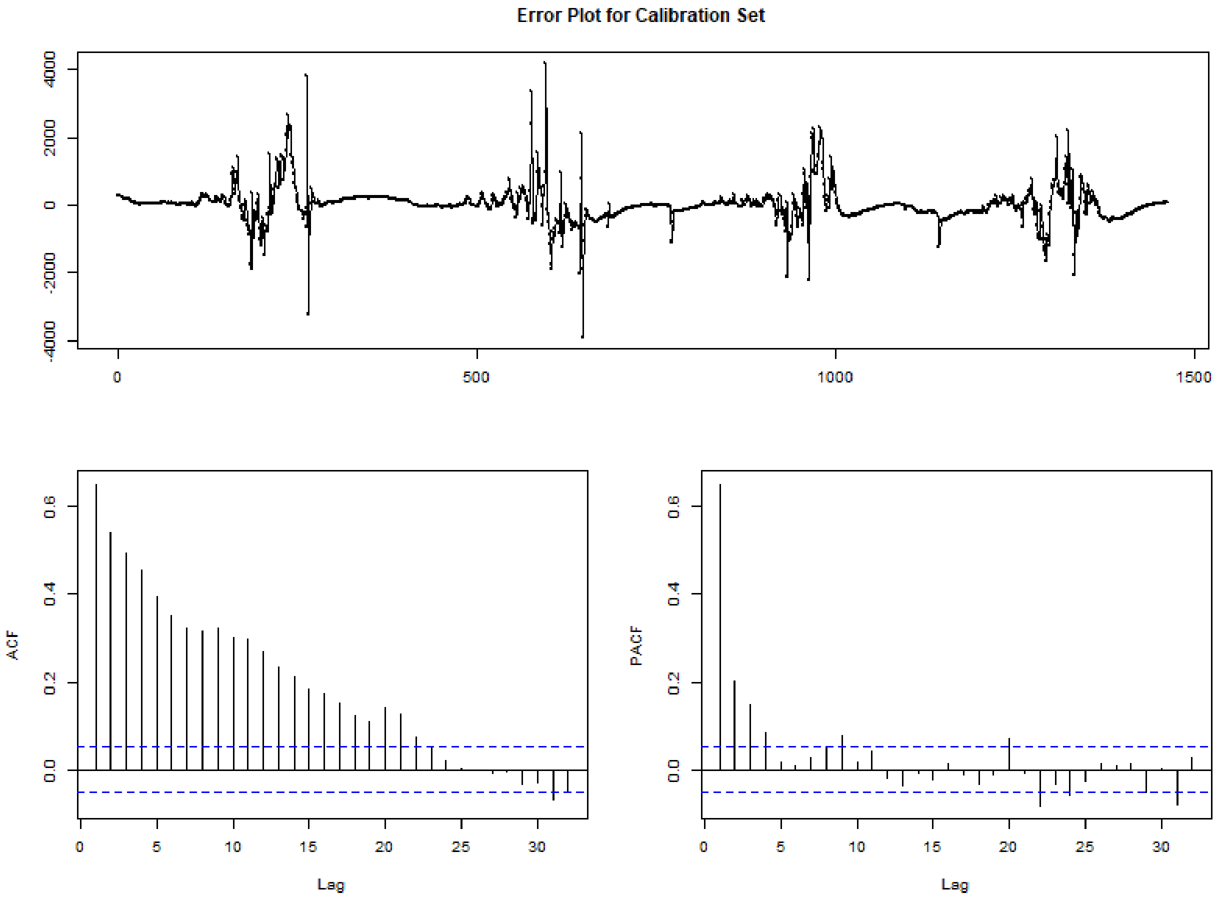

Figure 9. Error, ACF and PACF plot

The Box-Cox transformation parameter (λ) value was found to be 1.0463. The ARIMA model structure was identified as ARIMA (2,1,1) with coefficient $\varphi_1 = 0.3337$, $\varphi_2 = 0.0624$ and $\theta_1 = -0.8513$.

Figures 10 and 11 present the time series plot and scatterplot of observed and simulated flows at Chisapani station for calibration period after error correction. The figure clearly shows the improvement in predicting peak flows after error correction for calibration set. Figures 12 and 13 present the time series plot and scatterplot of observed and simulated flows at Chisapani station for validation period after error correction. It also shows the improvement in predicting peak flows after error correction for validation set.

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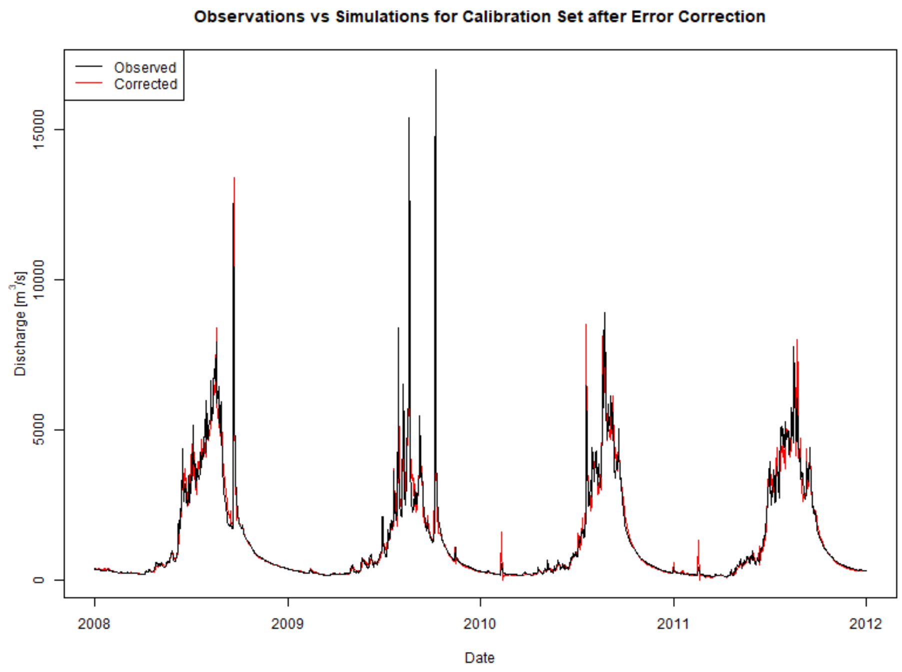

Figure 10. Time series plot for calibration set after error correction

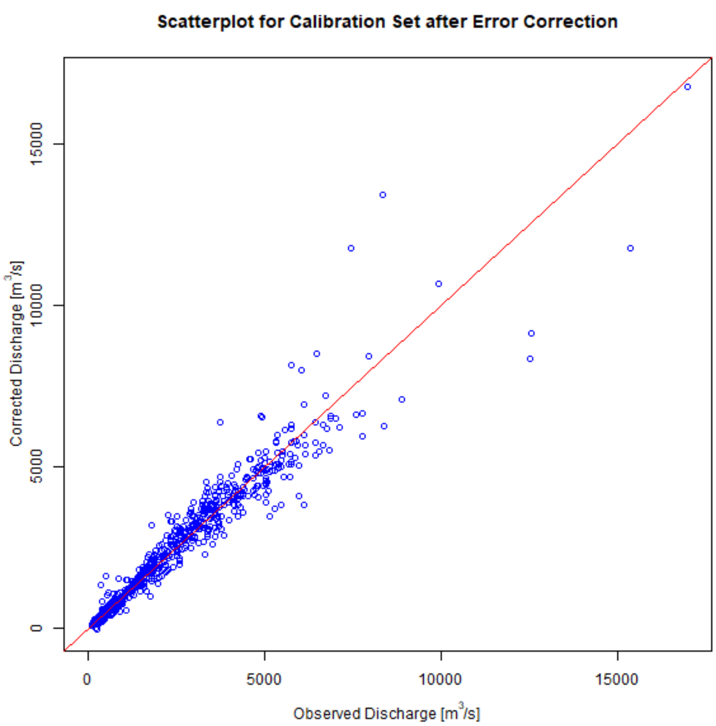

Figure 11. Scatterplot for calibration set after error correction

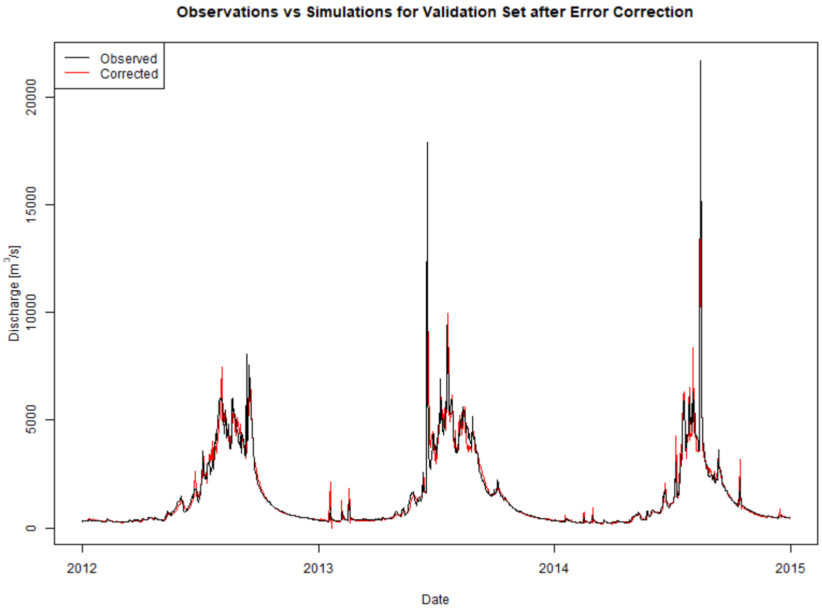

Figure 12. Time series plot for validation set after error correction

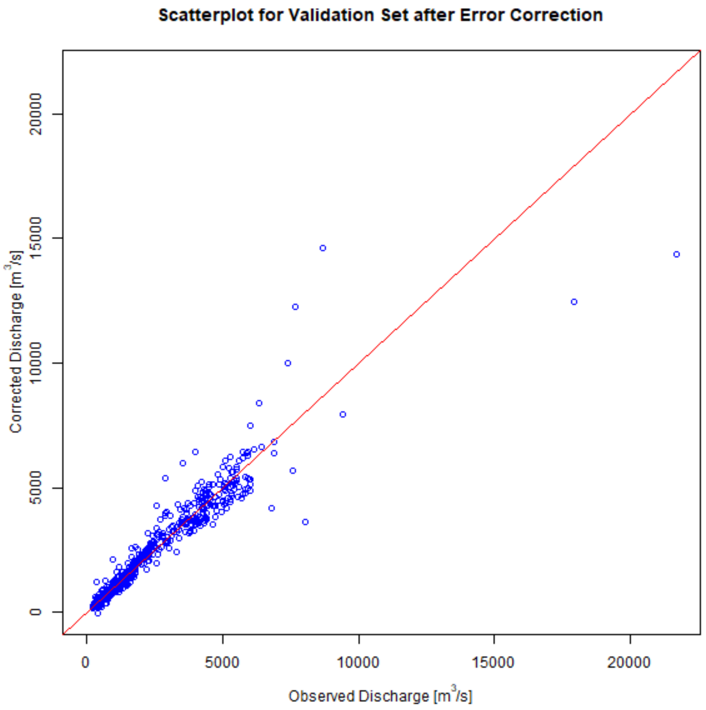

Figure 13. Scatterplot for validation set after error correction

Table 6 below summarizes the model performance before and after employing complementary error model.

Table 6. Summary of model performance

GOF measures	Calibration Set		Validation Set	
	TUWmodel only	**TUWmodel and Error model**	**TUWmodel only**	**TUWmodel and Error model**
me	-9.64	1.19	-134.14	1.44
mae	296.87	154.87	334.36	175.9
mse	275056	152559.4	372484.9	249920.7
rmse	524.46	390.59	610.32	499.92
nrmse %	29.5	22	34	27.8
PBIAS %	-0.7	0.1	-9.1	0.1
RSR	0.3	0.22	0.34	0.28
rSD	0.94	0.99	0.93	0.97
NSE	0.91	0.95	0.88	0.92
mNSE	0.77	0.88	0.74	0.86
rNSE	0.8	0.98	0.88	0.98
d	0.98	0.99	0.97	0.98
md	0.88	0.94	0.87	0.93
rd	0.94	1	0.97	1
cp	0.44	0.69	0.53	0.69
r	0.96	0.98	0.94	0.96
R2	0.91	0.95	0.89	0.92
bR2	0.85	0.93	0.79	0.89
KGE	0.92	0.97	0.87	0.95
VE	0.78	0.89	0.77	0.88

The results before error correction show that TUWmodel is good in conserving runoff volume with percent bias (PBIAS) -0.7% for the calibration period. The Nash-Sutcliffe efficiency (NSE) for calibration set was 0.91. The PBIAS for the validation period was -9.1%. The NSE for validation set was 0.88. After employing the error model, the calibration efficiencies calculated using the PBIAS and NSE metrics improved to 0.1% and 0.95 respectively. Corresponding values for the validation period also improved to 0.1% and 0.92 respectively. The relative index of agreement (rd) also improved from 0.94 to 1 for the calibration set and 0.97 to 1 for the validation set. This indicates that the time to the peak flow is exactly matching after employing error correction. The performance indices for both calibration and validation sets clearly show the significant improvement of the performance of TUWmodel after employing complementary error model.

5. DISCUSSION AND CONCLUSIONS

In this study, we presented an application of a complementary data-based error correction model to enhance the performance of a conceptual rainfall-runoff model for flood forecasting. A conceptual rainfall-runoff model TUWmodel was developed for Karnali basin in Western Nepal. Four years of daily data from 01/01/2008 to 31/12/2011 were used to calibrate the model. The calibration data set consisted of major flood events in 2008 and 2009. The parameters of TUWmodel were calibrated automatically using differential evolution optimization algorithm. The model was then validated using three years of daily data from 01/01/2012 to 31/12/2014. The validation data set consisted of historically high flood event of August 2014. Although, only seven years of data were used to calibrate and validate the model, the data set consisted of major flood events crossing the danger level. In recent years, such flood events haven't been observed.

The errors of the calibration set from the conceptual rainfall-runoff model were then analyzed to identify the bias, persistency and heteroscedastic behavior. We outlined a procedure for extracting useful information from the bias, persistency and heteroscedasticity exhibited by the error series. We also presented an automatic procedure to identify the model structure and the parameters of the complementary error correction model using a freely available R package 'forecast'.

A data-driven ARIMA model was developed from the error series of the calibration set and employed to correct the predictions made by the conceptual model on both calibration and validation set. Application of the error correction model to both calibration and validation data set revealed that this procedure could effectively improve forecast accuracy of the conceptual rainfall-runoff model. This shows that the accuracy of a flood forecasting system can be significantly improved by setting up a data-driven error correction model to complement a conceptual rainfall-runoff model operating in the simulation mode.

In operational flood forecasting, the precipitation and temperature forecast will be obtained from NWP model in gridded form. Basin average precipitation and temperature forecast need to be computed from gridded data. Both the rainfall-runoff model and the error correction model should be recalibrated for NWP inputs. Parameters of the conceptual rainfall-runoff model and error correction model will be calibrated automatically and kept unchanged during operational application. The automatic optimization module DEoptim provides an efficient method to update parameters of conceptual rainfall-runoff model whereas the auto.arima function provides an efficient method for automatically estimating parameters of error correction model. The whole system can be deployed in automatic operational forecasting mode by updating input time series in real-time.

The major limitations of this study are that daily data are used for calibration and validation of the model and the performance of the model isn't tested using NWP inputs. Sub-daily or hourly data aren't available for the study. Application of sub-daily or hourly data is required to capture the flood peak precisely. Although the data used in the model have covered historical peak events, longer length of data will help for better estimate of model parameters. We haven't tested the performance of the model in operational flood forecasting using NWP inputs and kept that research for future.

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Original paper

Learning from Voices in the Field: The Role of Disaster Education in Reducing Vulnerability in Urban and Rural Afghanistan

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Abstract Recent studies have shown that the frequency of natural disasters in the world has been increasing. This trend has had serious consequences for people throughout the world. Many studies have also found that in natural disasters, there is a general tendency that women are at higher risk than men. Several factors increasing the vulnerability of women in disasters have been elucidated. Among these, a lack of disaster education has been identified as a primary factor. This study is a follow up to a previous study carried out by the present authors in January 2017 in rural and urban communities in Afghanistan. In September 2017, a non-profit organization conducted a series of disaster education and risk assessment programs in many parts of Afghanistan, which included communities in both rural and urban areas. The aim of the present study is to understand the effect that the education program had on the two case study communities in Afghanistan. The data was collected by conducting focus group discussions and interviews, and analyzed using grounded theory. We found a positive effect of the disaster education program in the short-term by raising awareness, increasing knowledge and promoting actions. The study confirmed previous findings on disaster education's role in reducing the vulnerability of women. It also revealed that women can play a very important role at the time of a disaster, and they can be good agents for dissemination of the gained knowledge and information to the whole community. Recommendations include the need for follow-up studies in the near future in order to understand the medium and long-term effects.

Key words: Women's vulnerability, Afghanistan, Disaster education, Rural and urban communities

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1. INTRODUCTION

The number of natural disasters is growing in the world, inflicting serious consequences on people, property and the environment (Cvetkovic & Ivanov, 2014). It is known that in general, the effects suffered by people in natural disasters are not distributed equally, with more vulnerable populations suffering greater levels of harm. In this paper, we investigate one aspect of this general trend by considering the effect of gender as a determining factor in the rates of harm incurred by people in natural disasters.

There is strong evidence that in natural disasters, women are more vulnerable to injury and death than men (Enarson, 2009). However, it has also been found that the factors making women more vulnerable in disasters differ among societies (Aryabandu, 2009;Valdes,2009; Saad, 2009).

In Afghanistan also, it has been found that women and young girls are affected disproportionately in natural disasters (Oxfam, 2009). Hamidzada *et al.* (2019) found that access to disaster education is a key factor affecting the vulnerability of Afghan women in agreement with previous studies in other parts of the world (Takauchi and Shaw,2009; Parkinson,2014; Gokhali,2009; Meagan,2012). Plan International (2013) found that women are often prevented from receiving the same level of disaster education as men, and this increases their vulnerability. That study also pointed out that exclusion of women from disaster management processes results in a much higher probability of death in natural disasters for women and children, with a rate as much as 14 times higher than for men in developing countries. The fact that men and women do not have the same educational opportunities was highlighted in a 2003 United Nations document that stated: “men and women in a society do not have the same opportunities for education neither in ‘normal’ times, nor when a disaster strikes” (UNISDR, 2003. Cited in UNDP, 2010).

Nuemayer & Plumper (2008) identified factors related to culture, availability of resources and opportunities, and access to education affecting the rates of victimization in disasters. In a 2009 study, the United Nations Office for Disaster Risk Reduction (UNISDR, 2009) highlights the importance of disaster education for empowering women in disasters. The Hyogo Framework for Action (HFA) 2005-2015, priority for action 3, emphasizes the role of “knowledge and education” and highlights that disaster education and awareness raising are important components of disaster risk reduction. The Sendai Framework for Disaster Risk Reduction 2015-2030, emphasizes raising awareness and understanding disaster risk for reducing and preventing the risks, as a first priority for action.

However, providing a disaster education program in which women and men can participate, in some countries is a real challenge, such is the case of Afghanistan. Hamidzada *et al.* (2019) found that a lack of trained female staff, security and economic issues, as well as cultural and traditional practices represent challenges for the government to provide disaster education to women.

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The above studies underline the importance of inclusion of women in disaster education. Disaster education is emphasized as it is key in helping communities to be better prepared for disasters. The aim of this study is to understand the effect of a disaster education program on vulnerability factors by comparing the result of focus group discussions in rural and urban areas in Afghanistan before and after the implementation of the program. In the next sections we discuss the background of our study (section 2), and research approach (section 3). In section 4 we present the methodology of our study and in section 5 we present the discussion and results. Section 6 presents the conclusions of the study.

Vulnerability of women in disasters

Vulnerability is the degree to which people are at risk, this degree is not equal for all people (Susman and Wisner, 1983). Wisner et al. (2004) state that "Vulnerability refers to people's situation and ability to manage, tolerate and recover from the impact of a natural hazard." People around the world are vulnerable in disasters differently, but those who were vulnerable in pre-disasters, will be more vulnerable in disaster situations (Fordham, 1998). The literature shows that people who are poor and living in disaster prone areas are usually more vulnerable than others who live in safe places (Militie, 1999). This is true in both developing countries and developed countries (Bolin, 1982; 1986 cited in Enarson and Morrow 1998). Among all vulnerable groups in disaster situations, women have been found more vulnerable than men in disasters (Enarson and Morrow, 1998; Ikeda, 1996; Ishiq, 2011; Aryabandu, 2005).

The factors that make women more vulnerable in disasters vary in different societies. Aryabandu (2005) found that 60 % of poor people in the world are women. The author pointed out that this poverty is the result of marginalization. Some studies highlighted that ignoring women in decision making processes is a major factor of women's vulnerability in disasters in developed and developing countries. Ikeda, 2016 argues that other factors such as age, social connections, economic development level, wealth level, health condition are the main factors of women's vulnerability in disasters. However, many studies highlighted that care giving responsibility makes women more vulnerable in disaster situations as well (Enarson & Morrow, 1998; Ariyabandu, 2009). Denton (2012) found that due to unequal opportunity and access to resources, in developing countries 70 % of women in developing countries are living under the poverty line. This situation marginalizes them from all decision making processes, especially those related to environment and climate change (UNWOMEN, 2009).

Nelson et al (2010) argued that gender relations are not integrated in the climate change development policies as a result of gender blindness of policy makers(Nelson et al, 2010: 51). Neslon stated that in developing countries women are at high risk because of cultural norms in pre-disaster time (cited in Saleem, 2013). Women's care taking responsibilities of the whole household during disasters make them more vulnerable to natural disasters than men (Enarson, 2004).

2. ROLE OF DISASTER EDUCATION IN DISASTER RISK REDUCTION (DRR)

Disaster education efforts were strengthened in many nations since 1990, the International Decade of Natural Disaster Reduction (IDNDR). The positive role of disaster education in many studies has been highlighted as a tool to reduce disaster risk (Shaw et al, 2011). This has also been highlighted by UNISDR, which presents disaster education as one of the milestones for the Implementation of the Hyogo Framework for Disaster Risk Reduction (UNISDR, 2006).

In several studies, disaster education has been recognized as an important factor to help reduce disaster vulnerability. Shaw and Takeuchi (2009) noted the importance of disaster education for women, particularly in the disaster preparedness phase. Considering the role of women as good communicators in communities and families, their participation in community meetings regarding disaster education is an absolute requirement for preparedness. Nimpuno (2007) (as cited by Takauchi et al, 2011) suggests that women's level of knowledge and ability can be enhanced by participating in disaster education and preparedness. Thus, women can play a positive role to reduce the risk of disasters particularly in the areas of emergency health and sanitation as a part of disaster preparedness and risk reduction education. The author argues that women, being good communicators to their families, can effectively mobilize the participation of the whole community. Furthermore, Takeuchi et al. (2011) pointed out that instead of seeing women as a vulnerable category, they should be known for their positive roles in facilitating disaster education, preparedness and response during emergencies. The study added that women can be good agents for dissemination of the gained knowledge and information to the whole community (Takeuchi et al, 2011)

The influence of disaster education may differ between urban and rural communities (Takeuchi et al. 2011). The authors argued that disaster education in rural communities is typically transmitted from one generation to the next and that the key elements that influence disaster education are awareness of the local environment, and traditional and indigenous knowledge. Takeuchi et al. also explained that urban communities' living conditions are different from rural communities, thus education can less easily be transferred. The study pointed out that due to hectic schedules, urban people's social networks are weak, so the disaster education learning process is disconnected.

Our present study evaluated the role of a disaster education program on disaster vulnerability in a rural community and an urban community in Afghanistan. The education program comprised several activities including disaster education sessions, the development of Hazard, Vulnerability, Capacity and Risk Assessments (HVCRA), and the mapping of hazards by both women and men in each community. The disaster education program included an introduction to disaster risk reduction (DRR) concepts (e.g., hazard, risk, disaster, vulnerability and capacity), the disaster risk management process (preparedness, mitigation, prevention, response, reconstruction) and early warning systems.

With the NGO's guidance, participants prepared plans for community disaster management. These plans reflected the needs, concerns and issues affecting all of these groups. The education program lasted one week (5 days) and participants attended the program all day. Women and men attended the program separately. They also established men and women disaster risk management committees. In each community 4 committees were established: rescue, search, health, and early warning committees.

Both communities selected for the study, due to their geographical location, are subject to many kinds of natural hazards such as earthquake, flash floods, river flood, mass movement and drought. Among all mentioned natural hazards, flood hazards represent the biggest concern for both communities which have frequently caused loss of life and property. For example, in the urban community at least two flood events occur each year. Recently, a flood channel overflowed when it was blocked due to unplanned construction, affecting the whole village. In the rural community both flash flooding and river flooding occurs frequently. The frequent floods disrupt the community's normal life, usually causing damage to agriculture fields and loss of many agriculture products. Although flood hazards have been identified as the primary hazard for both communities, the disaster education program focused on all kinds of natural hazards.

Through the use of women-only and men-only focus group (FG) discussions in both the rural and urban communities before and after conducting the disaster education program, this study investigates the role of the education program on women's and men's disaster vulnerability. Furthermore, the study assesses the level of knowledge gained and the changes in behavior and attitude of men and women in each community.

2.1 The use of Focus Groups (FGs) in disaster studies

Focus groups have been used in disaster studies, particularly in feminist studies. Focus groups were first used by social scientists in the 1920s. In the 1980s, this method was used by market researchers and then by other professionals to do research on issues dealing with health, social sciences and others.

Focus groups have been found to be a valuable method for collecting data in women studies (Griffin and Madriz, 2003; willkson,1999; Krueger and Casey, 2000). By conducting FGs, it is possible to listen to many ideas and voices of participants instead of one single voice, so it allows researchers to understand the opinions and ideas of the group (Willkson, 1999). The method was particularly useful in Afghanistan, where literacy rates are low, and where cultural and traditional practices limit the possibility of approaching community members, especially women, through other methods. Hamidzada *et al.* (2019) found that data collection through the gathering of women in a FGs was effective, and encouraged participants to talk and express their ideas. In the present study, we conducted FGs with rural and urban men and women separately.

2.2 Grounded Theory

Grounded Theory (GT) was first proposed by Galser and Strauss (1965), and has gradually been recognized as an effective method for developing theory from data. By applying Grounded Theory, a researcher can obtain theoretical understanding through a systematic analysis of data (Charmez 2003). The first step in the GT process consists of coding and categorizing the data (Jones & Alony 2011) the; second step involves the construction of theory.

GT has been used for analyzing FG discussion results, especially in feminist studies (Evans 2013). Wuest (1995) noted that a strength of this method is that it can present a collective of all women's ideas, so all women's voices can be heard. The author also highlighted that "grounded theory" is consistent with postmodern feminist studies in the recognition of multiple explanations of reality" (Wuest, 1995, p. 127). The importance of this method in feminist or women based studies was also highlighted by Plummer and Young (2010) who found that GT can reflect the various issues represented or discussed.

In a 2017 study in Afghanistan, GT was used to analyze FG discussion data providing valuable insights on women's vulnerability factors and the inter-relationship of factors pre- and post-disaster (Hamidzada *et al.* 2019).

3. METHODOLOGY

This study was based on a literature review, a series of interviews, and FG discussions in two case study areas in Afghanistan: a) Kabul, an urban area; and b) Mazar, a rural area. FGs were held before and after the administration of an education program in the two areas.

For data analysis, we apply grounded theory (GT) in an effort to identify the effect of the disaster education program on women and men in each community by analyzing the FG discussion transcripts. In the following sections we summarize the data collection efforts and the application of GT.

3.1 Data collection through Interviews

A total of 11 interviews were conducted in the first and second round of our field trip. Four interviews with an Afghan National Disaster Management Authority (ANDMA) official including the state Minister for disaster risk management, four interviews with heads of local communities in rural and urban areas, two interviews with representatives of the NGO that conducted the education programs in rural and urban areas and one interview with representatives of United Nations Development Program (UNDP) Climate Change Project. Interviews and meetings with officials of ANDMA were conducted in their Kabul office.

Interviews with heads of communities* were held in their houses. Interviews with NGO and UNDP representatives were held in their own offices. The discussions during the interviews mainly focused on their views and awareness of the recent ANDMA activities, especially in the case study areas.

3.2 Data collection through focus group discussions (FGs)

A first round of FG discussions were conducted in January 2017, before the disaster education program, and a second round in November 2017, two months after the completion of the disaster education programs in each community. In total 51 women and 79 men participated in a total of 12 FG discussions. We conduct men only and women only FGs separately. In order to understand each group's attitudes, opinions and behavior, the participants were mainly from 3 groups of actors:

A) Women who had experienced a disaster,

B) Men who had experienced a disaster.

C) Government official or employees who were dealing with such cases daily.

Participants for the focus groups were selected from previous studies by an NGO. All participants in the female and male focus groups were almost the same in both periods. In the pre-education program FGs (January 2017) the researcher was accompanied and introduced by ANDMA and NGO staff who were familiar with and trusted by the community. In the post-education program FGs, due to the high security alert in the region, all NGOs suspended their missions. Thus, they did not allow the staff to accompany the researcher. Due to the high insecurity in the area, the authors depended solely on the community leaders to accept and support our idea of holding the FGs. The head of community gathered all the participants who attended the education program, and who had participated in the first round of FGs, in addition to some new participants for each of the FG.

Twelve new male participants were introduced in the FGs that carried out after the disaster education program. They were members of disaster risk management committees. Table 1 summarizes the distribution of participants in the FG in both case study areas in both periods.

The head of ANDMA office in Kabul was present at all FGs in Kabul. In Mazar, unlike in January 2017, as was indicated above, the NGO did not allow its staff to accompany the researcher due to security issues in communities neighboring the study area. Since most of community men and women were already familiar with the researcher's activity from her earlier study in January 2017, they warmly welcomed her and actively contributed to the FG discussions. The FGs in the rural area were held in the village community hall, while the urban FGs were held in the house of the head of the community.

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* In Afghanistan, a Head of Community is usually a respected, trustable member of the community who is electing by the members of the community

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The same set of questions prepared for each round, and the topics for discussion were given to both male and female groups in both the rural and urban communities. The data collected through the FGs were analyzed by use of Grounded Theory.

Table 1. Distribution of participants in the focus group discussions in Kabul and Mazar provinces in January and November 2017

Place / Group	Interviews (number of participants)		First round FGs (Jan.2017)			Second round FGs (Nov.2018)		Total
	Jan. 2017	Nov. 2017	Women	Men	DRR staff	Women	Men	
Number of FGDs			3	3	2	2	2	12
Rural area Mazar, Khulm district, Sayad village	2	2	9	7	10	12	20	58
Urban area Kabul, district 13	4	4	19	19	6	12	18	72
Total participants by gender	6 men	6 men	26	26	Male 15 Female: 1	24	38	51 female 79 male

3.3 Grounded Theory: Coding and categorizing

Full transcripts of all FGDs were prepared based on the field notes. Codes were selected by the researchers from the data on the basis of multiple repeated themes and issues that were highlighted by the FG participants. Each of the FG transcripts from the discussions were reviewed and coded individually. More than 500 codes were identified. Following review of the coding of all FGs, it was found that many codes were very similar and could readily be incorporated into a single category. Table 2 shows the coding process for the "Preparedness category" in rural and urban areas. Different categories were found to dominate for men and women, with many categories for women revealing the importance of disaster education for protecting women from hazards and disasters.

By comparing the FG discussion materials between the first and second round of FGs, the new responses clearly revealed the change in the level of understanding concerning disaster management. Table 3 and 4 show differences of responses before and after conducting the disaster education program in rural and urban communities. The effect that the disaster education program had on their knowledge and behavior became evident.

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Table 2. Examples of codes which fall under gaining knowledge and preparedness information from different focus groups in rural and urban communities

Discussion point	Women FG in rural community	Women FG in urban community	Men FG in rural community	Men FG in urban community
The benefits of disaster education program	We learned how to use emergency kits	We learned to protect our houses from flood by using sand bags	We learned that lack of safe drinking water caused many problems	We learned how to cleaning ditches and flood channels which helps to decrease flooding

Table 3. Comparison of disaster preparedness before and after the disaster education program was conducted in the urban area

Discussion point	Women before disaster education program (Jan. 2017)	Woman after disaster education program (Nov. 2017)	Men before disaster education program (Jan. 2017)	Men after disaster education program (Nov. 2017)
Action taken in a case of flood	They didn't know flood arrival until it arrived at their door due to lack of warning	Now they have warning system, using phones and know how to protect their house with sand bags	They rescued neighbors during the flood	Now they can announce early warning for all community and evacuate
Priority disaster reduction actions	They didn't know how and where to evacuate at the time of a disaster	Now they know safe places for evacuation and to call each other by mobile phones in order to warn them of possible flooding	They wanted to have proper and nice gutters	They learned how to clean the ditches and drainage canals to avoid urban flooding

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Table 4. Examples of the range of responses to the same question by different FGs before and after the disaster education program in the rural community

Discussion point	Women before disaster education program (Jan. 2017)	Woman after disaster education program (Nov. 2017)	Men before disaster education program (Jan. 2017)	Men after disaster education program (Nov. 2017)
Action taken in the case of flooding	After carrying the children, will come back to collect the remaining things	Evacuate to a safe place with together with children and do not return	Try to run to a secure place alone and if possible to help others	Help others, specially elders, children and woman
Priority disaster reduction actions	Need the safe space for an evacuation shelter	Now they understand where to go. They request more of these kind of disaster education programs.	Do not have proper drainage system and canalization	They can reduce risk in the community by maintaining the canals and ditches

4. RESULTS AND DISCUSSION

4.1 Results of the Interviews

In the interview with ANDMA and the NGO officials, they explained the recent activities of risk assessment and disaster education sessions. They elaborated that in addition to the training session, the communities were equipped with basic necessary disaster risk reduction instruments such as a siren for early warning, shovel and pick for digging the ground in order to find missing persons or things. They also donated to the communities some emergency first aid kits to use in emergency situations as well as other practical items such as warm clothes, blankets, and others. ANDMA and the NGOs officials expressed gratitude from community residents for their remarkable contribution and active participation in the risk assessment process. They highlighted the establishment of some emergency committees[**] consisting of men and women in both communities.

[**] The committees aim to assist communities at the time of natural disasters. For example, they distribute first-aid kits so that victims do not have to wait for aid to arrive from the DRR agencies which often can take several days.

The heads of both communities mentioned in the interviews that all donated equipment was now locked away in their communities. The rural community head informed us that some of the equipment such as the first aid kits was maintained in a room dedicated by a resident of this community as a health clinic. He advised that his community had used the shovel, pick and other equipment for digging a well. They had first taken a sample of the water to government laboratories to test its safety. This was confirmed so that now at least 40% of community residents benefit from this clean drinking water. The head of the urban community mentioned that when the NGO conducted the disaster education program, another organization had dug channels for the community to reduce blocking of drainage, and the amount of rain-water accumulating on the streets which has caused urban flooding.

4.2. Results of the Focus Group Discussions

Upon analyzing the FGDs many categories emerged, with analysis providing valuable information. The analysis showed that disaster education was effective for both men and women in the communities, but especially for women in both rural and urban areas. All analytic categories for each FGD were chosen according to the number of codes assigned to them. Sections 4 .1 and 4.2 below elaborate on the causal factors revealed upon conducting the disaster education program in rural and urban settings that clearly demonstrate the effect of the disaster education program on participants knowledge and behavior in both communities.

4.2.1. Results of FGs in rural area

A total of 12 women and 20 men participated in two separate FGs. Except for very few new participants (which were exceptionally accepted), most participants in the FGs were the same as those who participated in the first round of FGs on January 2017, prior to the NGO intervention.

A substantial change was observed in participants' behavior, knowledge and ability to explain disaster issues following the disaster education program. Participants could now elaborate many details about their training and expressed their willingness to learn more. Considering the low level of literacy in rural areas, especially among rural women, their understanding of the training program, especially concerning flood hazards, was commendable. The study team selected the category of "Information" from the several information-related codes presented by the FGs.

The Women FG participants said that they learned how to help themselves and others in a proper and secure manner in a disaster. Women also learned how to use first aid kits, and other equipment. They had already attempted to practice using the first aid kits on their children. They had also learned how to search for missing people following disasters. Inclusion of women in the emergency committees, which were established by the NGO was an important strategy for reducing the level of vulnerability of women in disasters. Women learned how to tackle the current problems in their community, thus they cooperated with men to establish a basic health clinic. They also assigned a respected woman in the village to help women in the clinic in the absence of a professional medical staff. During the first visit to this community in January 2017, it had been found that the lack of female staff in all disaster management cycles caused many problems for women, some serious enough to result in death (Hamidzada *et al*. 2019). Women's group members elaborated that they had learned how women can help other women by taking some primary actions. For example, they learned how to carry out search and rescue, and to provide first aid. From the above codes, a category of "Cooperation" also emerged. Table 5 shows categories found in rural and urban men and women FGs. Figure 1 shows the rural women's group in the practical session of the disaster education program by the NGO in March 2017.

Table 5. Different categories found in rural and urban communities FGs

Categories choose based on multiple codes	Rural		Urban	
	Women	Men	Women	Men
Information, raise awareness, gained knowledge on Disaster preparedness	o	o	o	o
Cooperation	o	o	x	x
Coordination	o	o	x	x
Planned economic empowerment project	x	x	o	x
Independency and initiation	o	o	x	x
Dependency on DRR agencies	x	x	o	o

Figure 1. Rural women's group in the practical session of disaster education training (Photo credits: IOM, 2017).

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Since most of the elderly women of the community are illiterate, which prevented them from reading and using additional training guidance materials, only young schoolgirls were considered ready to conduct training for other female members of their community.

Among men FGD participants, an even larger positive change was found regarding their knowledge. Men had mapped the risk, vulnerability and capacity of village people. From this they gained enhanced information and knowledge which encouraged them to take some initiatives to solve two main issues: access to safe drinking water and access to a health clinic. They used first aid and emergency kits to establish a basic health clinic for the community. They also used the equipment such as shovels, picks, etc. for digging a well. Thus, the study team chose a category of "Collaboration" from the above codes. In addition, men had established committees, defining roles and responsibilities and a readiness to train more people. Three committees have been established so far including a First Aid Committee, an Early Warning Committee and a Search and Rescue Committee.

Generally, in rural areas it has been found that an increase in residents' level of information on disasters leads them to work together collaboratively towards community resilience to natural disasters. In both male and female FGDs, participants explored the new information and knowledge that they gained through the Disaster Education sessions. The women's group explained that they have been assigned new duties in the emergency committees, which may help them in a disaster situation. Some of these women became members of rescue and investigation committees. They learned how to prioritize who to help and rescue first in a disaster situation. For example, men FG explained that they learned how to first help children, women and elders. Figure 2 shows the effect of the disaster education program on the three categories: Gain knowledge and preparedness, Collaboration, and Cooperation.

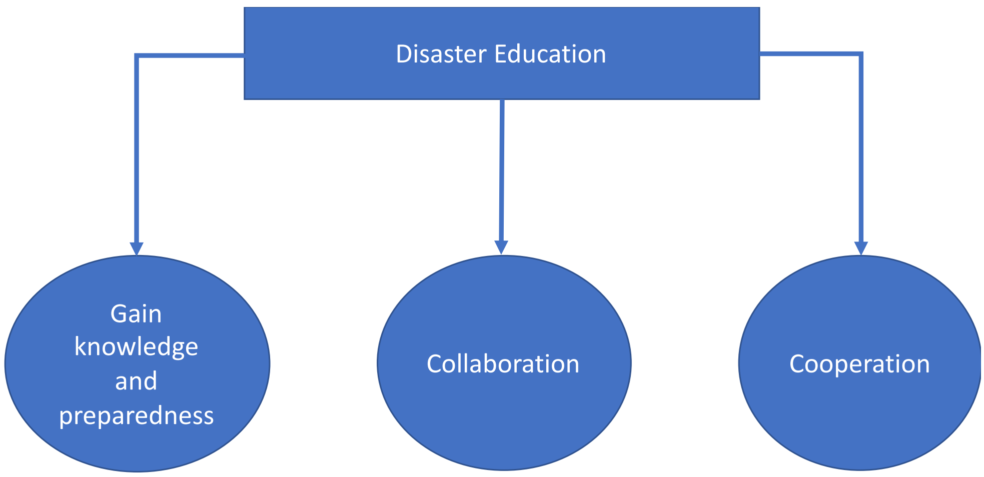

Figure 2. Effect of disaster education on the rural community behavior and knowledge

4.2.2. Results of FGs in the urban area

In the urban area, 12 women and 18 men participated in the FGDs. Most participants in the FGDs were the same as those who participated in the first round of January 2017, prior to the IOM intervention. Only few new participants in the second round of FGs were introduced by the head of the community.

The men's and women's focus groups actively participated in the Disaster Education sessions and risk assessment of their community. The FG discussion revealed that the participants gained information, and knowledge. They also learned about disaster preparedness. The women group was taught how to set up small projects. During the program, they planned to establish an embroidery workshop to support their families. Thus, this new "Planned economic empowerment project" was identified as another category resulting from the disaster education program in the urban area.

Urban community men and women groups also established emergency committees such as a First Aid Committee, an Information and Early Warning Committee, and a Search and Rescue Committee. The women's group said that the training was useful, and they learned how to prepare sand bags to prevent floodwaters from entering their houses. Urban men and women said they gained more knowledge and information on urban flooding and how to map the hazard in the community. They understood that inclusion of women in management of risks is very important. Therefore, they assigned some girls and women in the committees to help community members with special needs, especially to help other women at the time of disasters.

The women and men FGs mentioned that they learned where they should go or evacuate when there is danger of flooding. After participating in the disaster education program sessions, they established an early warning system by mobile phones. They receive the early warning calls from community heads and responsible emergency committees. They can contact the members of the emergency committees when they face problems. From the above codes, the study team selected a category called "Gain knowledge and preparedness."

The men's group had not planned any new action in their community up to the time of the study team's visit. The women's group planned to establish some handicraft and embroidery courses. These courses sought to produce embroidery for market sale to empower the economic situation of poor women in the community. Thus, it can be argued that disaster education contributed to self-sufficiency and empowerment of the community. We chose "Planned economic empowerment project" category from the above mentioned codes. Figure 3 shows that the disaster education program had a direct effect on "Gain knowledge and preparedness", and "Planned economic empowerment project".

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Figure 3. Effect of disaster education on the behavior and knowledge of urban community

5. DISCUSSION

This study investigated two communities, one in a rural and one in an urban area of Afghanistan. It explored how Disaster Education in both communities influenced people's behavior and attitudes and generally increased their awareness and information. It also explored people's motivation and action after participating in a Disaster Education program. The nature of discussion on the issues and accomplishments in implementing the Disaster Risk Reduction (DRR) plans, clearly illustrated the level of knowledge gained through trainings, and the urgency of needs in relation to the subjects being explained. For instance, the rural community needed safe drinking water, which is a human essential need. Upon receiving the equipment and training on Disaster Education, they realized the urgency of digging a well and did so.

In the urban community, there was no urgency for digging a well, so the equipment given by the NGO was not utilized immediately. The findings of the present study were compared with those of an earlier study in the same communities on their vulnerability factors in disasters (Hamidzada *et al.* 2019).

The findings of FGDs revealed that in rural communities the main categories or factors emerging from participation in the Disaster Education program were Collaboration, Gaining information and knowledge, and preparedness, and Cooperation. Both men's and women's attitudes and behavior regarding disaster risk reduction greatly improved following the training. Their greater knowledge and information on disasters enabled them to reduce the effect of disasters in their community. They could solve up to 50% of the essential problems for their community by digging a well to have access to safe drinking water and setting up a basic health clinic.

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In urban communities the primary categories were found to be Gaining information and knowledge and preparedness, and the proposal of a Planned Economic Empowerment project. Men and women gained greater information and knowledge about the hazards in their community. They identified a safe place for evacuation and established a basic early warning system through mobile phones. In emergency situations, they can call each other or the head of community. The women's group learned how to protect their houses by preparing some sand bags. Figure 4 highlights the outcomes of the disaster education program in rural and urban communities.

Overall, we found that the disaster education program increased the participants' knowledge and awareness about disasters and disaster preparedness in both urban and rural communities. However, in the urban community the program was less effective in empowering them to take action. For example, neither the women nor men had initiated any concrete action (at the time of the study) based on the training, while in the rural area it led to concrete actions. The following bullet points highlight some of the differences:

1- The rural community was more independent and took action and initiatives based on the training according to their knowledge and information level. The examples of digging a well to find a source of safe drinking water or establishment of a basic health clinic demonstrated this application.

2- In the rural community, men and women committee members made practical use of the equipment provided by the NGO such as tools for several purposes, and emergency response kits.

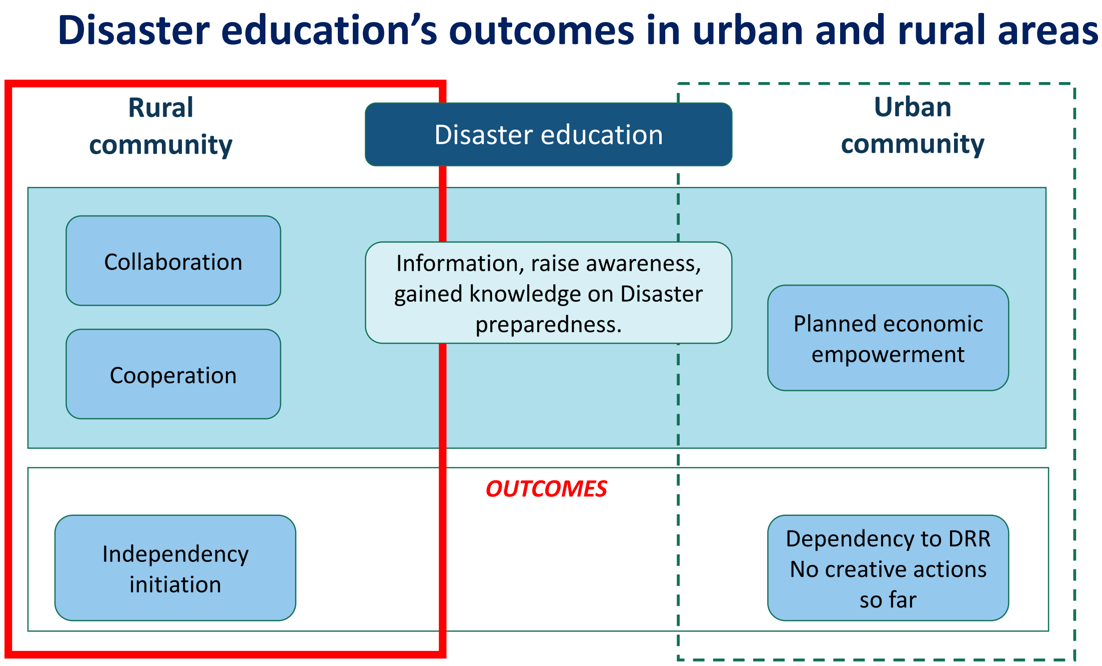

Figure 4. The disaster education program influence and outcome in rural and urban communities.

3- Women in the rural community played a positive role despite high levels of illiteracy in rural areas. Women were able to take positive steps towards reducing the level of hazard in their community (e.g., learned how to protect homes from flood waters by using sand bags).

4- An additional and major achievement following the disaster education program was the inclusion of women in the emergency committees in both urban and rural communities. It is a first step to empowering women, especially in Afghanistan. As discussed in the introduction, women can play a crucial and positive role in helping other women in all cycles of risk management.

5- Dependency of urban community: The urban community demonstrated more dependency on the government and the DRR agencies. They learned methods to reduce hazards in their community, but thus far demonstrated no independent action. For example, urban men learned how to clean and maintain the streams and canals, but never applied this knowledge. They had no plan to start such work, often citing the lack of budget or of resources for the lack of action.

In rural communities most people are working in the fields; in urban communities most participants have jobs outside their community. These factors may substantially contribute to the level of cooperation and independent initiatives by rural communities rather than within urban communities. The effectiveness of the disaster education program appeared to have greater impact in rural areas than in the urban area we examined.

The study results were similar to previous findings on disaster education’s role to reduce the vulnerability of women. For example, women learned what actions to take in the case of flooding to protect themselves and their families. In the rural community, the establishment of the health clinic for women provides the possibility for women to have access to female medical help in the case of injury or birth following disasters. The study also revealed that the influence of the disaster education program were different between urban and rural communities. We found that in rural communities, key elements that influence disaster education are awareness of their local environment, and traditional and indigenous knowledge. Similar results were observed by Takeuchi et al. (2011).

This study confirmed the findings of previous studies (Takeuchi et al. 2011; Loki 2015; UNDP 2013) that women can play a very important role at the time of a disaster, and they can be good agents for dissemination of the gained knowledge and information to the whole community.

6. CONCLUDING REMARKS

The main purpose of the study was to understand the effect that a disaster education program had on the two case study communities in Afghanistan. Data for the study was collected through focus group discussions and interviews, and the data was analyzed by grounded theory. In general, the program helped to raise awareness in both rural and urban areas. However, the study showed that the influence of the disaster education program were different between urban and rural communities, with a more visible effect in the rural community. In the rural community it proved to be very effective in motivating the community to take action resulting in greater self -sufficiency and empowerment. The study also confirmed the previous finding on disaster education’s role to reduce the vulnerability of women reported in the literature. Disaster education and awareness raising are important components of disaster risk reduction.

Thus, education and awareness raising sessions need to be increased and dissemination of messages on disaster risk should reach the communities. Accessibility of messages by women and diverse groups (the community level through community radios and community based gathering) is suggested.

It was confirmed by many FGs that lack of basic infrastructure increases exposure and contribute vulnerability of women and men in the communities. There is a serious need for special budget for construction of retaining walls, evacuation centers, ditches and flood channels. The budget and resources should allocate for early warning systems and recruit and train DRR female trainers and female staff too.

The voices and concerns of communities and local level actors in the national review of policies and law development, should be considered through bottom up approaches. Consideration of women’s view by conducting separate sessions and inclusion of female guides for them is also a strong step to reduce the level of vulnerability.

Further research should include the analysis of the long-term effects, as well as to understand if the knowledge and information, and motivation gained and observed during this study will continue in the long run.

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Original paper

Community Resilience and Crime Prevention: Applying the Community Engagement Theory to the Risk of Crime

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Abstract Citizens are increasingly expected to take a more participatory role in society, which increases the need for them to be knowledgeable about a wide range of uncertain risks and to properly prepare themselves in case these risks become reality. To date, most attention regarding risk preparedness has focused on natural hazards. In the past decade, however, human-made safety risks have gained notoriety in the public's eye. The purpose of this paper is to examine whether the psychological drivers on an individual, community and institutional level of the Community Engagement Theory also apply to the context of social safety hazards such as crime. The study was conducted via an online survey. In total, 1245 Dutch citizens who were already a member of the citizen panel of their municipality at the time of data collection participated in the online study. The results of this research show that the Community Engagement Theory is not only applicable for natural hazards, but also for human-made risks such as crime. Psychological drivers of all three levels, individual, community, and marginally institutional level, are relevant in explaining the willingness to report and intervene when witnessing a crime. This research gives insight and guidance for policy makers and practitioners regarding stimulating reporting and intervening behavior of crime, and citizens information-gathering.

Key words: Crime, Reporting behavior, Information gathering, Community Engagement Theory

1. INTRODUCTION

Citizens are increasingly expected to take a more participatory role in society, requiring them to act as caregivers, prevent and help solve crime, and mitigate the consequences of hazards and disasters. In the context of public safety, this shift towards a shared responsibility between the government and citizens increases the need for the latter to be knowledgeable

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about a wide range of uncertain risks and to properly prepare themselves in case these risks become reality (Yetano et al., 2010). In the Netherlands, for example, citizens living in areas below sea level need to prepare themselves for a serious flooding, as a quick evacuation will probably not be feasible in such a situation (Kerstholt et al. 2017).

To date, most attention regarding risk preparedness has focused on hazards such as floods, tsunami's and earthquakes. In the past decade, however, social safety disasters have gained notoriety in the public's eye. The 9/11 terrorist attacks, and the more recent terrorist attacks near Christmas markets in Berlin in 2016 and Strasbourg in 2018, for instance, have had their impact throughout the Western world (Haridakis and Rubin, 2005), and the same can be said for other human-made risks, such as those pertaining to technological hazards, cybercrime, organized crime, and crime undermining local authority and interfering in businesses (RIVM 2016). These types of crimes have disruptive effects on individuals and communities alike. Terrorist attacks, for example, may strike fear in the heart of citizens (Haridakis and Rubin 2005), and affect the community by pitching groups within societies against each other. Crime undermining local authority may have disastrous consequences for the regular economy and the quality of society (Broekhuizen et al. 2018). Criminal money invested in legitimate businesses may for example result in unfair competition, and drug shacks, hemp plantations and synthetic-drug laboratories may pose physical risks in the form of nuisance, noise, fire, and chemical spillage (Lam et al. 2018). Taken together, it is increasingly realized that crime risks can have severe negative and dislocating effects on the community, stressing the importance of making communities resilient to crime. For the scope of this research, we define a community as 'a group of people with diverse characteristics who are linked by social ties, share common perspectives, and engage in joint action in geographical locations (MacQueen, et al., 2001; e.g. in this context the neighborhood they live in).

Since most citizens would know the ins and outs of their own neighborhood, they would be the most likely candidates to know where criminal activities are likely to happen and to actually recognize crime in action. As such, they can have a valuable role in crime prevention and as sources of crime-related intelligence for the police (Terpstra 2009, Bullock and Sindall 2014). In the past decade, governments have increasingly pursued opportunities for citizen engagement and citizens, in turn, have become more aware of possibilities to actively participate (Yetano et al. 2010). These developments are perhaps best signified by the increase in a number of so-called online neighborhood watches in the Netherlands[*]. Often involving both citizens and police officers, these online neighborhood watches provide an online means to connect people with the aim to prevent crime and increase crime-solving rates by signaling suspicious activities in their neighborhood (Schreurs, Franjkić, Kerstholt, De Vries & Giebels (2020), WABP 2018, Pridmore et al. 2018, Lub 2016). This greater

[*] Online neighborhood watches are a rising phenomenon in The Netherlands. This is a type of citizen participation in the social safety domain. Neighbors start groups via the application WhatsApp in order to prevent and detect crime in their neighborhood. These groups are mostly used to report incidents or suspicious circumstances to their neighbors. The group generally has administrators (e.g. neighbors who started the group) who regulate communication via groups. In some cases, the neighborhood police officer is also a member or in contact with the group administrators. The groups differ in how professional they are set up, and vary in the amount of members (from covering inhabitants living in one street up to an entire block; Schreurs, et al., 2020; Mehlbaum & Van Steden, 2018; WABP 2018).

demand on citizens to partake in the fight against crime on the one hand, and the increasing opportunities for them to do so on the other, underscores the importance to know which psychological factors drive people to actually take these opportunities.

Multiple well-known psychological theories have been developed to predict citizens' preparatory and adaptive behavior for hazards and disasters, for example the Protective Action Decision Model and the Protection Motivation Theory (Terpstra 2011; Lindell & Perry 2012; Floyd, Prentice-Dunn & Rogers 2000). These theories, however, mainly address individual- and social-related factors. Another theory aiming to predict citizens' preparatory behavior, called the Community Engagement Theory (Paton, 2013; Paton et al. 2008), takes into account institutional-related drivers as well. This theory proposes that *individual* beliefs, social network characteristics in the *community*, and the relationship between community and *institutions* influence the extent to which citizens are willing to receive information and to use this information to prepare for hazards. The Community Engagement Theory has been described as an all-hazard theory: it has been validated for disasters such as floods, tsunamis, and earthquakes, and across different cultures (Paton et al. 2013). To date, however, the domain of application has not been extended beyond the context of natural hazards; consequently, applicability to social safety risks such as crime has yet to be assessed. Furthermore, as far as we know, no research has been conducted in the social safety domain which has examined individual, community, as well as institutional factors simultaneously. While it is expected that all three perspectives would be relevant to citizen participation in the social safety domain, as it can be performed individually, in collaboration with other citizens (e.g., neighbors or bystanders) and/or in collaboration with the police. In the present study, it will therefore be examined whether the psychological drivers on an individual, community and institutional level of the Community Engagement Theory also apply to the context of social safety hazards such as crime.

Applying the Community Engagement theory to the risk of crime

According to Paton (2013), dealing with uncertainty represents a common denominator in people's experience of various hazardous events. In the example of a flooding, citizens may be uncertain about the exact time and place of the flooding, its intensity, and its potential consequences (Kerstholt et al. 2017). Taking preparatory action can be seen as a means to cope with these uncertainties. This should be no different from the risk of becoming a victim of crime: whether or not citizens would become a victim of crime is highly uncertain, as is the severity of the crime itself and its consequences for individuals and their community.

Obviously, exactly which specific preparatory actions are required would depend on the nature of the risk. For an earthquake, these actions can for example consist of protecting your house to avoid that it collapses during an earthquake and stock up on food and water (Paton et al. 2010), whereas for a flooding one could acquire an emergency kit or knowledge on how to evacuate or where safe locations can be found (Kerstholt et al. 2017). These preparatory behaviors aim to mitigate negative consequences in case the specific risk occurs. For crime, mitigation may involve reporting a suspicion of crime to the police through the correct channels or discussing such suspicions with neighbors. Preparations would then be to get information on how to act when a crime occurs, for example, how to report to the police, using which channels, or how to intervene.

Crime is a special domain in comparison to the domain of natural hazards, in the sense that the police has a monopoly on violence. In crime prevention, citizens are not free to do anything they want, but are bounded by laws and regulations. This emphasizes the relevance of relationships between citizens and institutions as the police: collaboration between the former and the latter should ensure that citizens abide by these rules and do not take the law into their own hands. However, citizens increasingly act out of their own initiative, do not always seek contact with the police, and do not always adhere to these rules or regulations. A government’s vision of a greater citizen participation in the fight against crime may therefore increase the risk that this participation turns into vigilantism, where citizens, for example, use unauthorized violence or violate the privacy rights of the suspect (Haas et al. 2014, Lub and De Leeuw 2019). Ideally, therefore, citizens should not act fully independently. Police officers, or the police as an organization, should assist citizen participation by informing them about the relevant laws and regulations, and provide some oversight to ensure these are abided by. For example, a burglary in progress should be stopped by citizens calling in the help of the police, rather than apprehending the suspect themselves, and, perhaps, use violence (Jackson et al. 2013).

All in all, it could be argued that the Community Engagement Theory’s all-hazard applicability would also apply to how people make choices in actual information gathering and whether they are willing to act when crime occurs (for example by reporting to the police and intervening when witnessing a crime).

Psychological drivers

The Community Engagement Theory takes into account psychological drivers on three levels, the individual, community and institutional level.

Individual level

The individual level includes beliefs regarding the hazard, as well as regarding the appropriate preventive or responsive behavior. Risk perception is one of these individual drivers. Operationalized as the perceived likelihood of the risk to occur and the perceived severity of the consequences (Paton et al. 2008), a higher risk perception has been shown to lead to more information seeking (Ter Huurne and Gutteling 2008).

Previous research on preparatory behavior for hazards has shown that whether people see themselves as capable to perform the specific behavior, also known as self-efficacy, will influence whether they will actually perform that behavior. Besides self-efficacy, also response efficacy (also called outcome expectancy), i.e. the belief, whether the advised behavior will have the anticipated effect, is expected to increase preparatory behavior (Paton

2013, Floyd et al. 2000). A previous study in the context of crime, specifically on membership of an online neighborhood watch, for example, showed that citizens who believed that joining such a group would lead to a reduction of crime were more likely to become a member of an online neighborhood watch (Authors Manuscript submitted for publication). Additionally, information in risk communication perceived as high in self-efficacy and response efficacy increases the likelihood that citizens prepare themselves for flood risk (Kievik and Gutteling 2011).

In the police domain, and in crime prevention specifically, morality plays an essential role (Cromby et al. 2010). In order for citizens to report crime or intervene, they first have to decide whether they classify certain behavior they have witnessed, for instance, someone stealing a bicycle, as right or wrong (Harkness and Hitlin 2014). Experiencing a conflict with their moral values, then leads to the experience of moral emotions such as anger or disgust (Haidt 2003), in turn motivating behavior such as reporting the crime to the police. Further, previous research has shown that the experience of negative emotions (for example fear) will influence people’s eagerness to gather information about a risk and courses of action (Nabi 2003). In the case of crime, this information could be about courses of action regarding reporting crime to the police or intervening when being a witness of crime. Hence, for the purpose of this study morality was added to the individual level in the form of moral values and moral emotions.

Community level

On the community level, the Community Engagement Theory takes several drivers into account. The first one is a citizen’s sense of community, entailing to what extent they feel connected with their neighborhood (Ohmer and Beck 2006, Paton and Johnston 2001). Second, citizens may also experience a certain degree of collective efficacy, meaning that citizens feel that they are capable as a community to perform a certain action (Ohmer and Beck 2006, Hipp 2016), for instance, to protect the community against crime. Third, whether citizens have participated in their community on a broad range of domains in the past (e.g., organized a street barbecue, attending public meetings or joined a neighborhood crime watch) is expected to increase the likelihood of reporting and intervening behavior when the occasion arises. By participating in the community, citizens engage in social contacts, making it easier to gather information on how to act. This in turn might increase confidence to act again in the future (Paton et al. 2013).

Institutional level

In crime prevention, the institutional level is just as, or maybe even more, important than in the case of a natural hazard. When acting on criminal activity in their neighborhood, citizens may either directly contact the police, or are very likely to encounter the police in the process. Additionally, citizens are probably more likely to assist the police by intervening or report a crime to them when they trust the police (Stoutland 2001, Jackson and Bradford 2010, Bradford, Sargeant, Murphy, & Jackson, 2017), and see the police as a legitimate authority (Tyler and Fagan 2008, Jackson et al. 2013). Finally, according to the Engagement Community Theory, citizens are more likely to engage in the public domain when they feel empowered. This means that when citizens feel that they have influence on (local) government policy and that their opinions are heard by the local governments, they are more likely to participate in the public domain (Paton 2013), e.g., by reporting crime to the police or by citizen intervention.

Present study

In the present study, it will be examined whether the Community Engagement Theory also applies to the context of a human-made risk, namely to the risk of being exposed to crime. This paper investigates the relation between psychological drivers on the individual, community and institutional level with 1) actual information gathering about how to report to the police and how to be able to intervene as a community (as a way to measure preparatory behavior), and 2) the willingness to act if crime did occur to them or in their neighborhood (as a way to measure intentional behavior after the risk has occurred).

2. METHOD

Participants and procedure

In total, 1245 Dutch citizens participated in the online survey. They were asked to participate through the citizen's panel of three municipalities located in the south of The Netherlands. Participants were already members of the citizen panel of their municipality at the time of data collection, and received an email whether they would like to participate in an online study on reporting and intervening behavior regarding crime in their neighborhood. The response rate across municipalities was 18.7%.

The survey started with asking for informed consent and some demographic questions regarding age, gender, and education. After this they filled in questions regarding psychological variables on the three levels of the Community Engagement Theory. Next, participants filled in questions regarding their willingness to act on crime in the future. They were not given a particular type or seriousness of crime, as it was supposed to be a general willingness to act on crime occurring in their neighborhood. Participants were asked which type of crime they thought of when answering these questions about their willingness to act. Main crimes mentioned were burglary, drug related crime, vandalism, theft and arson. Also, some additional questions regarding membership of neighborhood-WhatsApp groups and open questions regarding their motivations to act were asked. However, since they provided no additional information, they will not be elaborated upon in this paper. At the end of the survey, actual information gathering was measured by asking participants whether they were willing to receive information regarding how to report to the police and how to organize themselves in a neighborhood-WhatsApp group. When they agreed, they actually received the information.

Measures

Dependent variables

Actual information gathering was measured by asking participants whether they were willing to receive information regarding how to report crime and how to organize themselves in a neighborhood WhatsApp group. Their answers were recoded into “no” (not willing to receive any information; coded as 1) and “yes” (willing to receive information about reporting and intervening; coded as 2). When they wanted to receive information, participants actually received links to the information. Because of constraints on lengths imposed by one of the municipalities this variable was only asked in two of three municipalities (N= 762).

Willingness to report and intervene was measured by asking participants whether they were willing to act themselves in crime situations. Participants reported to what extent the following four items were applicable to them; “I would call the police when I witness crime”, “I would discuss suspicious circumstances with a police officer”, “If I were to witness a crime, I would be inclined to intervene to try to stop the offender” and “Together with my neighbors, I would take the initiative to prevent crime in my neighborhood” (scale 1 = not at all applicable, 5 = very applicable, α = .70).

Independent variables

All independent variables described below were measured on a 5-point Likert-scale, unless described otherwise. They were all based on the items used in the Community Engagement Theory (Paton, 2013), except for the construct of ‘moral values’ and ‘negative emotions’. The items were adapted to the context of social safety (e.g. the focus of risk perception was on crime instead of on a natural hazard, and efficacy focused on the ability to create a safer neighborhood, and organizing as a community in order to prevent crime).

Individual level

Risk perception was measured by asking participants how likely they thought it was that crime took place in their neighborhood (*Crime Likelihood*, five statements, α = .87, e.g. “How likely is it that crime is taking place in your neighborhood?”) and that crime would lead to certain consequences (*Crime Consequences*, five statements, α = .86, e.g. “How likely is it that crime will result into major damage to your house/possessions?”; Paton et al. 2008).

Moral values were measured by asking participants how important they felt that specific moral values, as defined in a study by Steg et al. (2014), were guiding principles in their live (scale: 1 – not important, 7 = very important). The values consisted of altruistic (four statements, α = .76, e.g. “social justice”, “helpful”, “a world at peace” and “equality”) and egoistic values (five statements, α = .73, e.g. “wealth”, “social power”, “influential”, “ambitious”, “authority”).

Negative emotions were measured by asking respondents how they felt when thinking about the possibility of crime taking place in their neighborhood. Respondents were specifically asked for four emotional states (four statements, α = .89, e.g. “afraid”, “worried”, “angry”, and “furious”).

Self-efficacy was measured by asking respondents how much they perceived themselves to be capable of contributing to a safer neighborhood (six statements, α = .82, e.g. “I know how to report crime to the police” and “I consider myself capable to prevent crime in my neighborhood”).

Response efficacy was measured by asking participants to what extent they thought specific measures they could take would be effective (six statements, α = .78, e.g. “participating in a neighborhood-WhatsApp group promotes the safety in my neighborhood”).

Community level

Sense of community was measured by giving participants statements regarding their connection with the neighborhood (eight statements, α = .91, e.g. “I feel connected with the people in my neighborhood”).

Collective efficacy was measured by asking to what extent they perceived that they were able to solve problems in collaboration with other neighbors (six statements, α=.85, e.g. “In difficult situations, as a neighborhood, we are able to work together on a solution”).

Community participation was measured by asking participants about their previous experience with a broad range of community participation as well as regarding reporting and intervening behavior specifically (nine statements, α = .81, e.g. “I attend neighborhood activities such as a neighborhood barbecue or party”, and: “I have called the police in the past to report crime”).

Institutional level

Trust in the police was measured by asking participants to what extent they trusted the police based on Stoutland (2001) and Bradford, et al. (2017; nine statements, α = .93, e.g. “you can trust the police when you need them” and “the police does everything it can to prevent crime”).

Police legitimacy was measured based on previous research of Tyler and Fagan (2008). Reliability score was relatively low (α = .66), a factor analysis showed that taking only the positively framed items into account had a higher reliability (five statements, α = .89, e.g. “In general, the police are a legitimate authority and people have to obey the decision of police officers" and "You have to do what the police tell you to do, even if you do not like the way they treat you".)

Empowerment was measured by asking participants to what extent they felt they could have influence on what happened in their neighborhood on an institutional level, and was based on research of Paton (2013; eight statements, α = .80, e.g. "Voting in local elections affects what is being dealt with in the neighborhood" and "I believe that elected representatives take my opinion seriously").

3. RESULTS

Descriptive statistics and correlations

Means, standard deviations and correlations for the dependent and independent variables are shown in Table 1. As we had a large sample, we tested for multicollinearity between independent variables. This was not the case, as all VIF's were below 3 (while below 5 is recommended) and tolerance levels were above 0.2 (Ringle et al. 2015). In total, 55.7 % of participants were willing to receive information. The willingness to receive information (no = 1; yes = 2) was positively correlated with risk perception – crime consequences (r = .13, p < .01), risk perception – crime likelihood (r = .13, p < .01), negative emotions (r = .14, p < .01), altruistic values (r = .12, p < .01), egoistic values (r = .07, p < .05), collective efficacy (r = .09, p < .05) and previous community participation (r = .09, p <.05), and negatively correlated with trust in the police (r = -.08, p < .05). Whether citizens were willing to report and intervene, correlated positively with altruistic values (r = .14, p < .01), egoistic values (r = .08, p < .01), self-efficacy (r = .36, p < .01), response efficacy (r = .44, p < .01), sense of community (r = .22, p < .01), collective efficacy (r = .33, p < .01), past community participation (r = .37, p < .01), trust in the police (r = .35, p < .01), police legitimacy (r = .19, p < .01) and empowerment (r = .23, p < .01).The municipality correlated with the willingness to receive information (r = -.08, p < .05).

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Table 1. Means, standard deviations, reliabilities and intercorrelations among the variables

Variables	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Actual information gathering[a]	1.56	.50	-														
2. Willingness to act	2.83	.90	.10**	-													
3. Risk perception – Crime consequences	3.08	.83	.13**	.01	-	-											
4. Risk perception – Crime likelihood	2.81	.87	.13**	-.02	.67**	-											
5. Negative emotions	2.55	.98	.14**	-.01	.52**	.56**	-										
6. Altruistic valuesb[b]	6.00	.91	.12**	.14**	-.06*	-.05	-.07*	-									
7. Egoistic valuesb[b]	3.56	1.04	.07*	.08**	.06*	.07*	.16**	-.02	-								
8. Self efficacy	3.34	.68	-.08	.36**	-.05	-.12**	-.11**	.09**	.13**	-							
9. Response efficacy	3.28	.67	.07	.44**	-.23**	-.23**	-.23**	.20**	.10**	.37**	-						
10. Sense of community	3.59	.74	.07	.22**	-.22**	-.19**	-.15**	.16**	.13**	.20**	.30**	-					
11. Collective efficacy	3.31	.62	.08*	.33**	-.17**	-.14**	-.15**	.20**	.15**	.26**	.40**	.54**	-				
12. Community participation	2.32	.73	.09*	.37**	.24**	.12**	.20**	.01	.17**	.25**	.17**	.26**	.34**	-			
13. Trust in the police	3.21	.73	-.08*	.35**	-.27**	-.25**	.27**	.21**	.03	.25**	.76**	.30**	.34**	.08**	-		
14. Police legitimacy	3.57	.73	-.01	.19**	-.09**	-.08**	-.05	.05	.09**	.10**	.28**	.12**	.14**	.12**	.41**	-	
15.Empowerment	3.10	.71	.07	.23**	-.16**	-.17**	-.18**	.20**	.10**	.18**	.43**	.29**	.45**	.19**	.46**	.23**	-
16. Age	59.76	12.34	.18**	.00	.01	.01	.04	.08*	.01	-.06	-.01	.10**	.00	.01	.03	-.09**	-.01
17. Gender[c]	1.39	.49	-.02	-.05	-.01	.03	.02	-.08	-.13**	-.12**	.01	-.02	.03	-.08**	.07*	-.06*	.04
18. Education	n/a	n/a	-.01	.00	.00	-.07	-.13**	.03	-.05	.02	.02	-.03	.04	.10**	.02	.03	.16**
19. Years in neighborhood	21.47	13.72	.09*	-.05	.01	.00	-.00	-.03	.00	-.02	-.04	.12**	-.06	.01	.01	-.06	-.11
20. Municipality	n/a	n/a	-.08*	.06	.00	.23**	.19**	-.01	.07*	.07**	-.08**	.06*	.03	.05	-.12**	-.10**	.03

Note. * *p*<.05, ** *p<.01,* [a] *1=No, 2=Yes,* [b] *measured on a 7-point scale (opposed to a 5-point scale),* [c] *1= male, 2=female*

Regression analyses

Actual information gathering

A multilevel logistic regression analysis was conducted with actual information gathering (1 = no, 2 = yes) as dependent variable, the municipality as grouping variable and the psychological drivers as covariates. The results (see Table 2) showed that Risk perception – crime likelihood (β = .40, p = .003), negative emotions (β = .29, p < .01) and altruistic values (β = .24, p < .01) were positive predictors and self-efficacy (β = -.43, p < .01) was a negative predictor for the willingness to gather information. Egoistic values were marginally significant (β = .13, p =.083). The variance between municipalities was not significant (p=.62), and the accuracy rate of predicting information gathering was 62.2%

Table 2. Multilevel binary logistic regression analysis of psychological drivers on actual information gathering about how to report and organize as a community to prevent crime (No=1, Yes=2), with municipality as grouping factor

Variable	B	S.E. β	t	*p*	Exp (B)
Risk perception – Crime consequences	-.20	.13	-1.62	.105	0.82
Risk perception – Crime likelihood	.40	.13	2.95	.003	1.49
Negative emotions	.29	.10	2.85	.005	1.34
Altruistic values	.24	.09	2.71	.007	1.28
Egoistic values	.13	.08	1.74	.083	1.14
Self-efficacy	-.43	.13	-3.34	.001	0.65
Response efficacy	.12	.19	0.64	.523	1.13
Sense of community	.11	.13	0.82	.410	1.11
Collective efficacy	.12	.16	0.73	.468	1.13
Community participation	.13	.13	1.00	.318	1.13
Trust in the police	.26	0.18	1.43	.153	1.30
Police Legitimacy	-.14	0.13	-1.14	.255	0.87
Empowerment	.04	0.13	0.33	.738	1.05

N=762, accuracy rate 62.2%

Willingness to act

A multilevel linear regression analysis was conducted with the willingness to act as dependent variable, the municipality as grouping variable and the psychological drivers as covariates. The results (see Table 3) showed that self-efficacy (β = .22, *p* <.01), response efficacy (β = .36, *p* <.01), collective efficacy (β = .13, p =.01) and past community participation (β = .30, *p* <.01) were positive predictors for the willingness to act. Police legitimacy (β = .06, *p* =.054) and trust in the police (β = .09, *p* =.083) were marginally significant. The variance between municipalities was not significant (*p* <.50). SPSS does not provide an explained variance for multilevel regression analyses, but since the municipalities did not have an effect on the model, a linear regression analyses was conducted which showed the same significant predictors and an R^2 of .32.

Table 3. Multilevel linear regression analysis of psychological drivers on the willingness to act, with municipality as grouping factor

Variable	B	S.E. β	T	*p*
Risk perception – Crime consequences	.03	0.03	0.77	.445
Risk perception – Crime likelihood	.03	0.04	0.74	.457
Negative emotions	.01	0.03	0.47	.636
Altruistic values	.04	0.02	1.61	.108
Egoistic values	-.03	0.02	-1.23	.219
Self-efficacy	.22	0.04	6.32	.000
Response efficacy	.36	0.05	6.73	.000
Sense of community	-.02	0.04	-0.48	.633
Collective efficacy	.12	0.05	2.64	.008
Community participation	.30	0.03	8.74	.000
Trust in the police	.09	0.05	1.74	.083
Police Legitimacy	.06	0.03	1.93	.054
Empowerment	-.05	0.04	-1.33	.184

N=1245, R^2 =.32

4. DISCUSSION

This study examined whether the Community Engagement Theory by Paton and colleagues would also apply to a human-made risk, specifically to crime. This paper investigated the relation between psychological drivers on an individual, community and institutional level with actual information gathering about courses of action and with the willingness to act after being exposed to crime.

Results showed that actual information gathering was only influenced by factors at the individual level, and not by factors at the community and institutional level. On the individual level, risk perception showed to influence information gathering. This result is in line with previous research by Ter Huurne and Gutteling (2008), showing that risk perception has a direct effect on the intention to seek information on chemical transport. The present study showed that this is also the case for the risk of crime occurring. When citizens perceive the likelihood of a crime to occur as higher, they are more likely to gather information about the risk.

Additionally, citizens scoring higher on altruistic values such as social justice, were more often inclined to gather information. This is in line with previous research, in which moral values are generally known to increase moral behavior (Steg et al., 2014, Bardi and Schwartz 2003). When people have high altruistic values, they might be more motivated to help society and gather information on how to mitigate the risk of crime.

Our results did show that when participants experienced more negative emotions (e.g. being afraid and angry), they were also more likely to be willing to receive information. Previous research also showed that in order to cope with these negative emotions, it is likely that the need for information increases, which in turn increases actual information gathering regarding the courses of action about the risk (Nabi 2003). Furthermore, citizens felt less capable to act (lower self-efficacy) were more willing to gather information. Furthermore, when citizens felt less capable in reporting crime and intervening, they are in need of information regarding courses of action of the risk in order to increase their feelings of capability. This corresponds with research of Kievik and Gutteling (2011) showing that when information regarding risk communication is perceived as high in self-efficacy, it increases the likelihood that citizens prepare themselves for flood risk.

The willingness to act was influenced by factors at all three levels, the individual and social level, and marginally by the institutional level. As such our results are in line with Community Engagement Theory and elaborates the applicability of this model to other domains such as crime.

Citizens who felt more capable of reporting and intervening (self-efficacy) were more willing to act when a crime would occur. Interestingly, citizens with a low level of self-efficacy were more willing to receive information, while citizens with higher self-efficacy were more willing to report and intervene. This suggests that it might be useful to provide information which increases people's self-efficacy (Kievik and Gutteling 2011). Further, citizens who believed that reporting and intervening would be effective in fighting crime (response efficacy) increased the willingness to act. This is in line with the Community Engagement Theory on natural hazards (Kerstholt et al. 2017, Paton 2013).

On the community level, citizens with higher beliefs of collective efficacy, meaning that they felt capable as a community to deal with crime, were more willing to report and intervene. Also, citizens who had participated more in their community were also more willing to act. This also corresponds with the Community Engagement Theory, as well as with previous research on citizen participation in the police domain (Authors Manuscript submitted for publication, Paton et al. 2013). Reporting and intervening behavior can be seen as a social behavior, citizens might discuss crime with their neighbors before reporting it and by participating on other domains in the neighborhood will increase their social contacts and knowledge, making them feel more confident of being capable to act again in the future.

The institutional level only had a marginal effect, showing that citizens with a higher trust in the police and who saw the police more as a legitimate authority were more willing to report and intervene.

When looking at the difference between informing and acting it can be seen that the first was only influenced by psychological drivers on the individual level, while the latter was influenced by the individual, community and marginally by the institutional level. An explanation could be that seeking and information gathering is typical individual behavior, while reporting and intervening behavior is more related to the community since the crime is probably not only affecting the individual but the community as well. Possibly, people would not like to intervene on their own considering the risks intervening might have (e.g. getting into a fight) but would like to rely on neighbors to help them if necessary. Furthermore, the institutional level did not influence information seeking at all, while it would be expected that at least police legitimacy would have a significant effect, since reporting and intervening behavior is also likely to be linked to the police (Jackson et al. 2013, Gill et al. 2014). It would be recommended in future research to also examine motivations behind the (un)willingness to gather this information. However, these were only marginally significant. One possible explanation is that the level of trust and legitimacy are quite high (means of 3.21 and 3.57 respectively and low in variety (SD's are both .73), which could be due to a bias in the sample via citizen panels. Another explanation could be that low as well as high levels of police legitimacy can increase information gathering and the willingness to act. Citizens feeling high levels of legitimacy might be very motivated to participate with the police by reporting and gathering information how to, while citizens who experience low levels of police legitimacy are more motivated to act on their own and are less interested in collaboration with the police. Future research could look into the role of high and low legitimacy.

Furthermore, this study did not examine causal relations between individual, social and institutional factors, however, correlations do show a pattern that all three levels are interrelated. This does reinforce the notion that all three groups of factors of the Community Engagement Theory are relevant to the context of social safety hazards such as crime. This does reinforce the notion that all three groups of factors of the Community Engagement Theory are relevant to the context of social safety hazards such as crime. Future research is needed to examine exact relationships between these perspectives.

The willingness to receive information and to act only correlated with each other weakly. Since this was not an experimental but a correlational study, based on these results it cannot be concluded whether the willingness to report and intervene increases after receiving the information. It would be interesting for future research to examine whether giving citizens information with courses of action would actually increase their willingness to act.

Limitations

This study does come with some limitations. First of all, this study did not measure actual reporting and intervening behavior, but only the intention. This might have influenced the results. It was expected that when citizens are asked about their intention, they have more time to think about their behavior and make an analytic decision. On the other hand, when they would actually be exposed to crime, more intuitive decision processes, like emotions, would have more weight in the decision to behave in a certain way. However, a measure of actual information gathering behavior was included. Citizens were asked whether they were willing to receive information about how to report crime, after which they actually received this information.

Secondly, for this study existing citizen panels were used to collect data. This might have caused a selection bias, since citizens who are willing to be a member of these voluntary citizen panels are already a selection of more active citizens. This might have increased the willingness to receive information and to report and intervene in the future. Furthermore, the response rate was quite low, which might have led to sampling bias. Nonetheless, we believe that the results of this study, and the application of the Community Engagement theory to the social safety domain can act as a starting point for future research. Although the sample varied broadly in age and the years respondents lived in their neighborhood, in future research it would be recommended to take a more representative sample of society. The main interest of this paper was however to examine the influence of psychological drivers on citizens' willingness, which was possible to do by using this sample.

Practical implications

The findings of this study give practitioners in the field (i.e. police and municipalities) some insight in the psychological drivers behind reporting and intervening behavior. When institutions want citizens to be informed about how to keep their community safe and how to participate, they should mainly focus on the individual level. For example, by stressing that the information can help to increase feeling capable to act effectively when necessary in order to increase self-efficacy and response efficacy (Kievik and Gutteling 2011). When trying to increase reporting and intervening behavior, the community level is also of importance. One recommendation is to focus on increasing citizen participation in communities, by organizing events and meetings and trying to involve large groups of citizens. When citizens have participated before and have more knowledge about how to report and what to do when they come across suspicious circumstances or crime, they are more likely to participate again in the future. When designing strategies, especially on increasing intervening behavior, it is important to keep in mind that this could also come with some negative effects, such as citizens taken the law into their own hands.

Concluding, the Community Engagement Theory is not only applicable for natural hazards, but also for human-made risk such as crime. Psychological drivers on all three levels, individual, community, and marginally institutional level, are relevant in explaining the willingness to report and intervene when witnessing a crime. Human-made safety risks are gaining importance in society (such as terrorism, organized crime and crime undermining local authority). As these hazards can have great negative and dislocating effects on the community, it is of extra importance to have insight on the psychological drivers to take preparatory actions, further increasing societal resilience.

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