Rainfall could Trigger More Large (ML≧6.0) Earthquakes: A Case Study for Taiwan

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ABSTRACT

This study objectively investigates the potential of rainfall that could trigger the earthquake from the earthquake number (ML≧6.0) and rainfall information during the time period from January 1995 to August 2012. (Lin 2013) reported the similar work that the typhoons could trigger small earthquakes easily especially after Chi-Chi earthquake during January 1995 to July 2012. The earthquakes are likely to have significant positive relationship with rainfall after the Chi-Chi earthquake with Chi-Square test. The result revealed a significant difference between the correlations of daily-accumulated rainfall values and earthquake activities both before and after the Chi-Chi earthquake. The significant difference has been discussed regarding changes of crustal conditions after the Chi-Chi earthquake.

Keywords: Ordinary earthquakes, Chi-Chi earthquake, Earthquake activity, Chi-square test

INTRODUCTION

The topic of rainfall and typhoon induced earthquakes has been researched (Husen et al. 2007; Lin 2013). (Husen et al. (2007) reported a series of 47 local earthquakes in the central Switzerland Alps that occurred three days after record rainfall during August 19-23, 2005. In studies conducted in Denver, Colorado, liquid waste has been injected into faults, resulting in increased seismicity at depths of up to 4 to 5 km. The researcher recorded 1500 minor earthquake events, which subsided after the injections ceased between 1962 and 1966. (Lin 2013) researched the typhoons triggered small earthquakes easily after Chi-Chi earthquake, with 102 typhoons during January 1995 and August 2012. In this study, a statistical analysis of earthquakes in Taiwan island between January 1995 and August 2012 is performed to test whether rainfall can trigger large earthquakes with the **Richter Magnitude** (ML≧6.0) (Table.1 and Table.2). The time without ML≧6.0 earthquake activity is not listed.). The daily average-accumulated rainfall values are the averages of the rain gauge stations near the epicenters of the earthquakes and the earthquake activity located offshore of Taiwan is not considered. The true monthly accumulated rainfall values are the multiple of 28, 30 or 31 (days) for the daily average-accumulated rainfall values (a month period). The true monthly accumulated rainfall values were also used by Chi-square test, the results were the same as using the daily average-accumulated rainfall values, and however the computing time is much more. Thus the daily average-accumulated rainfall values were used due to almost same period of a month (28, 30 or 31 (days) for a month period).

ANALYSIS METHOD

The Chi-square test (a type of statistical analysis) is conducted to confirm the correlation between two independent data sets (same dimension), and an asymptotic significance value (p-value) is then used to determine significant differences and strong relationships between

the two data sets, e.g., when the p-value is adequately small ($p < 0.05$) (Bewick et al 2004; Lawrence et al. 2006).

DATA ANALYSIS, RESULTS

The data of Table.1 and Table.2 are used by the Chi-square for the previous time-period to determine the difference in the correlation between daily rainfall value and earthquake activity before and after the Chi-Chi earthquake. Using the Chi-square test, the p-value is 3.581×10^{-12}, which is very less than 0.05 and therefore, a strong significant difference exists between the correlations. Figure 1 shows the relationship between the number of the earthquakes in a month (N) and the daily-accumulated rainfalls (R), and the results of the Chi-Square Test. Blue circles and red crosses indicate the N-R relationships before and after the Chi-Chi earthquake during January 1995 and August 2012, respectively. Three downward curves (lines) covered the blue circles indicate the N-R relationship before the Chi-Chi earthquake and the best-fitted equation for the N-R relationship is $LogN = -0.144 + 0.102LogR$ (blue line in Figure 1). (1)

Three upward curves (lines) covered the red crosses indicate the N-R relationship after the Chi-Chi earthquake and the best-fitted equation for the N-R relationship is $LogN = -2.501 + 0.802LogR$ (red line in Figure 1). (2)

The correlation is low, with a slightly negative coefficient of **+0.40**, before the Chi-Chi earthquake. The N-R relation is approaching the equation (1). Therefore, the earthquake activity has been associated with heavy rainfall during this period slightly. On the contrary, the correlation is high, with a positive coefficient of **+0.73**, after the Chi-Chi earthquake, while the N-R relation is approaching the equation (2). During this time period, then, the earthquake activity is increased during periods of heavy rainfall. These results, covering a period from 1995 to 2012, include activity both before and after the Chi-Chi Earthquake that may like create significant changes in the conditions of crustal stress, allowing rainfalls to trigger the large ordinary earthquakes.

DISCUSSION

The Chi-Chi earthquake may have resulted in crustal changes in stress conditions throughout Taiwan, forming some blind faults (Tsou et al. 2011) and causing existed faults to become unlocked. Such situation may have then allowed rainfall to trigger earthquakes. Previous results indicate the high likelihood of rainfall-induced earthquakes due to the creation of non-rigid layers after the Chi-Chi earthquake. True cause is arguable; although some possible reasons have been discussed in Section 1. One potential cause is worth mentioning that level and pressure variances in groundwater due to rainfall (Yeh et al. 2008; Saar et al. 2003). Then water from rainfall may change groundwater levels while simultaneously inducing slight stress and pressure redistributions near the faults according to Mohr-Coulomb failure criterion (Hoek et al. 2002), thereby triggering more large earthquakes although their depths are a little thick.

CONCLUSIONS

This study found that the correlation between daily rainfall and earthquake activity, before and after the Chi-Chi earthquake, is significantly different. It is possible that changes caused by the Chi-Chi earthquake made crustal conditions suitable for subsequent rainfall-triggered earthquakes. Potentially, heavy rainfall might have triggered two particular earthquakes observed in this study.

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Table.1 This Table shows the earthquake activity related to daily accumulated rainfall values from January 1995 to September 1999 (Source: Central Weather Bureau, Taiwan).

Year	*Month*	*Earthquake Number*	*Daily accumulated rainfall values*
1995	6	1	170.0mm
1996	3	1	130.5mm
1996	7	1	12.0 mm
1997	7	1	20.0mm
1997	10	1	40.0mm
1999	6	1	23.5.0mm
1999	9	8	80.0mm

Table.2 This Table shows the earthquake activity related to daily accumulated rainfall values from October 1999 to August 2012.

Year	*Month*	*Earthquake Number*	*Daily average-accumulated rainfall value*
1999	10	2	38.0mm
1999	11	1	19.0mm
2000	2	1	20.0mm
2001	2	1	25.0mm
2001	6	2	43.5mm
2001	12	1	14.5mm
2002	2	1	13.0mm
2002	3	1	15.5mm
2002	5	2	40.0mm
2002	8	1	26.0mm
2002	9	1	14.5mm
2003	6	1	40.0mm
2003	12	1	26.0mm
2004	5	1	14.7mm
2004	11	2	50.0mm
2005	3	1	30.5mm
2005	5	1	37.0mm
2005	6	1	29.5.0mm
2006	4	2	40.5mm
2006	7	1	30.0mm
2006	8	1	37.0mm
2006	10	2	43.0mm
2006	12	2	42.5mm

2007	1	1	25.0mm
2007	4	1	24.0mm
2007	9	1	35.0mm
2008	1	1	30.0mm
2008	6	1	31.0mm
2008	12	1	29.5mm
2009	7	2	47.0mm
2009	8	1	20.3.0mm
2009	10	1	22.8.0mm
2009	12	1	24.3.0mm
2010	2	1	26.0mm
2010	3	1	20.0mm
2010	4	1	30.0mm
2010	8	1	20.1mm
2010	11	1	23.0mm
2011	3	1	22.0mm
2011	4	1	24.0mm
2012	1	1	30.0mm
2012	2	1	28.0mm
2012	6	2	40.0mm

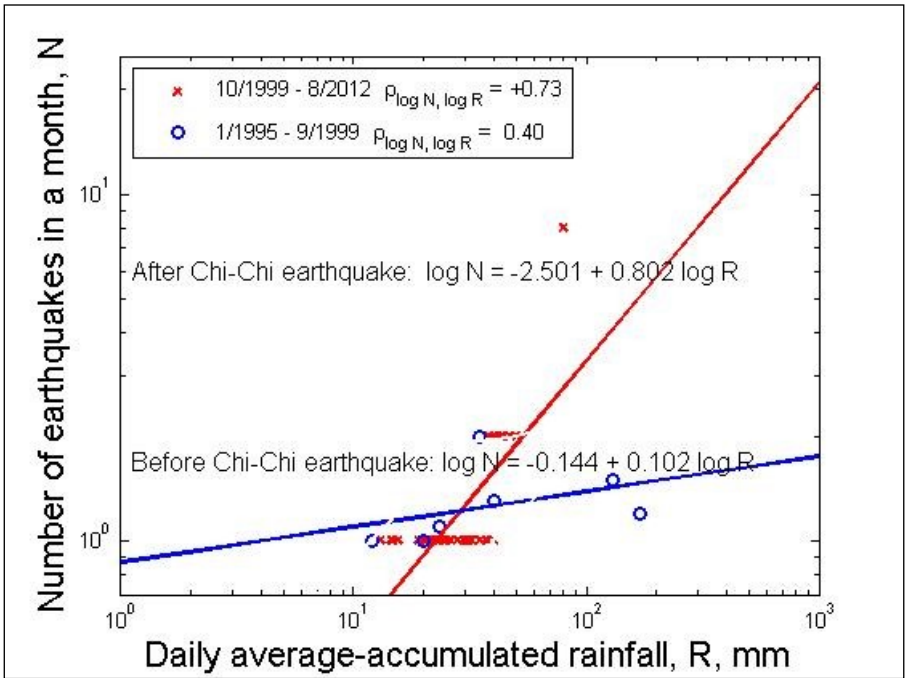

Figure 1. Correlations between the number of earthquakes (ML ≧6.0) in a month (N) and daily average-accumulated rainfall value (R) before and after the Chi-Chi earthquake (in log-scale) during the time from January 1995 to August 2012.

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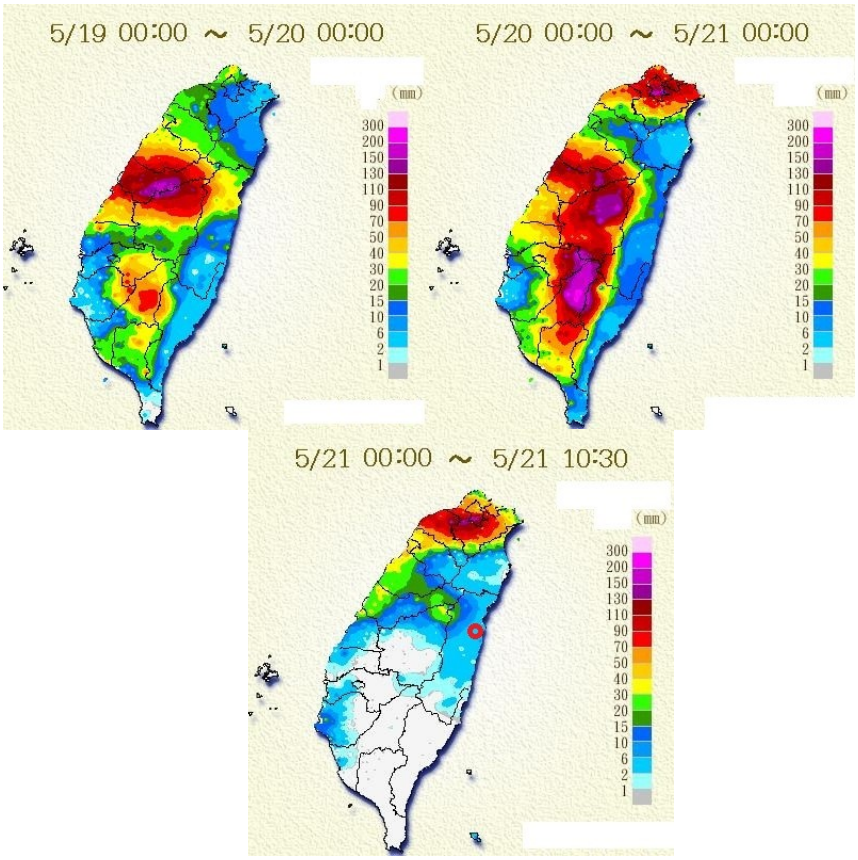

Figure 2. The accumulated rainfall values in Taiwan from 19 to 21 May 2013 (before 10:30 clock, local time). A circle indicates an earthquake occurred at 08:21:14.4 on 21 May 2014 (local time) with the depth = 18.0 km and ML =5.9 and the epicenter is at ($22.74N$,$121.45E$) after two-daily heavy rainfall. This earthquake would be doubted that was triggered by the rainfall.

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