Chapter

Resilience Science for a Resilient Society in Natural Disaster Prone Countries

Yoshiyuki Kaneda

Abstract

Recently, many destructive natural disasters occurred in the world. Therefore, the damage reductions and disaster mitigation for resilient society are very important and significant. For the implementation of these issues, we propose the resilience science including science, engineering, medicine, and social science. In social science, there are sociology, economics, psychology, law, pedagogy, etc. After 2011 earthquake in East Japan in which severe tsunami damages in a broad area occurred, the reconstruction and restoration activities in each area have been done; however, the progress speeds are not so rapid generally. One of reasons in which delayed reconstruction and restoration occurred is the shortage of pre-recovery plan and concept of future community in each area. In this chapter, we propose the resilience science for resilient society. The resilience science is based on multidisciplinary research fields, and the resilient society is defined as the society equipped with redundancy, robustness, elasticity, and safety. Especially, human resource cultivation is very important in resilience science for the resilient society. For the bright future, the resilience science for the resilient society based on human resource cultivation is indispensable.

Keywords: resilience science, natural disaster, disaster mitigation, recovery, restoration, human resource cultivation, philosophy, bright future

1. Introduction

The world experiences many natural disasters, such as tsunamis, earthquakes, volcanic eruptions, tornados, hurricanes, floods, landslides, and droughts.

Attention has been particularly drawn to destructive tsunamis and earthquakes, such as the 2004 Sumatra earthquake and tsunami, the 2010 Chile earthquake, and the earthquake and tsunami of East Japan in 2011. Recently, destructive earthquakes and tsunamis occurred at Lombok Island, Sulawesi Island, and Sunda Strait in Indonesia.

As per my personal experience, people, buildings, environment, and societies in coastal areas suffered severe damage with disasters, tsunamis, and earthquakes.

Following what has happened after the Great East Japan earthquake in 2011, having the huge damage by the natural disasters, the rapid restoration and the revival could not be seen in the coastal areas.

Many reasons can be mentioned here, such as the lead times, the reconstruction budgets, and the time spent generating agreement for the restoration plans among the national government, local government, and people living in coastal areas.

Farther, for each individual, it is much far from attaining their ordinal mental and economic conditions back to their state before the disaster [1].

What is indispensable in advance of the coming mega earthquakes, tsunamis, and heavy rain/storm/landslide, etc. is more advanced, progressive countermeasures for disaster mitigation, restoration, and revival in coast regions. I would like to define the natural disasters and mitigation as follows:

1. Natural disasters are events beyond human assumptions:

    - Disasters are various events caused by lack of common recognition, knowledge, and information.
    - Disasters are events caused by incomplete countermeasures.
    - Disasters are events that can be reduced by research/technology, countermeasures, enlightenment/education, human resource cultivation, etc.

2. For disaster mitigation:

    - Preparedness
    - Awareness
    - Science and technology
    - Early warning and proper evacuation/behavior
    - Knowledge and drill
    - Pre-reconstruction/resilience plan
    - Human resource cultivation

In this chapter, we will discuss certain measures for disaster mitigation, such as resilience science [2].

1.1 Tsunami and earthquake damage in the world

As I have already mentioned in a previous publication, "there are records of the 1575 Valdivia earthquake and tsunami in Chili, the 1700 Cascade earthquake and tsunami in Western Canada and Northwestern United States, the 1707 Hoei earthquake/tsunami in Southwest Japan, the 1755 Lisbon earthquake/tsunami in Portugal, the 1960 Chilean earthquake/tsunami, the 1964 Alaskan earthquake/tsunami, the 2004 Sumatra earthquake/tsunami, and the Great East Japan 2011 earthquake/tsunami (**Table 1**). In Japan, recently, many natural disasters included earthquakes and tsunamis have occurred and have caused serious damage [3] (**Figure 1**).

Based on the lessons we learned from the 2011 Great East Japan disaster, we discuss tsunami disasters and the recovery efforts.

Table 2 shows the examples of tsunamis caused by great earthquakes in the history of Japan. These historical tsunamis caused enormous damages over wide areas, especially along the coast.

DOI: http://dx.doi.org/10.5772/intechopen.85329

Year	Earthquake/tsunami	Area	M
1498	Meio earthquake	Japan	M8.2–8.4
1556	Shaanxi province earthquake	China	M8.0
1693	Catania earthquake	Italy	M7.4
1700	Cascadia earthquake/tsunami	US/Canada	M9.0
1703	Genroku earthquake	Japan	M7.9–8.2
1707	Hoei earthquake	Japan	M8.6
1716	Peru earthquake	Peru	M8.8
1739	Ningxia earthquake	China	M8.0
1746	Peru earthquake	Peru	M8.6
1755	Lisbon earthquake/tsunami	Portugal	M8.5
1759	Lebanon/Syria earthquake	Lebanon/Syria	M7.4
1771	Yaeyama earthquake/tsunami	Japan	M7.4
1778	Iran earthquake	Iran	M7.4
1783	Messiah Italy earthquake	Italy	M6.9
1789	Antakya earthquake	Turkey	M7.0
1850	Szechwan earthquake	China	M7.5
1854	Ansei earthquake	Japan	M8.4
1855	Ansei Edo earthquake	Japan	M6.9
1868	Chile/Peru earthquake	Chile/Peru	M8.8
1868	Ecuador/Columbia earthquake	Ecuador/Columbia	M7.7
1891	Nobi earthquake	Japan	M8.0
1896	Sanriku earthquake/tsunami	Japan	M8.2
1899	Alaska earthquake	USA	M8.6
1906	Off Columbia earthquake	Columbia	M8.8
1908	Messina earthquake	Italy	M7.1
1920	Haiyuan earthquake	China	M8.5
1923	Kanto earthquake	Japan	M7.9
1938	Alaska earthquake	USA	M8.3–M8.7
1939	Erzincan earthquake	Turkey	M7.8
1952	Kamchatka earthquake	Russia	M9.0
1960	Chile earthquake	Chile	M9.5
1964	Alaska	USA	M9.2
1995	Kobe earthquake	Japan	M7.3
1999	Izmit earthquake	Turkey	M7.8
1999	Chi-Chi earthquake	Taiwan	M7.7
2001	Indian/Pakistan earthquake	Indian/Pakistan	M8.0
2001	Bam earthquake	Iran	M6.8
2004	Sumatra earthquake	Indonesia	M9.1
2008	Wenchuan earthquake	China	M8.0
2010	Haiti earthquake	Haiti	M7.3
2010	Chile earthquake	Chile	M8.8
2011	East Japan earthquake	Japan	M9.0

After SSJ chronological scientific table, excerpt.

Table 1.
The destructive earthquakes and tsunamis.

Figure 1.
Damages by 2011 East Japan earthquake (after associate professor Sakamoto of Nagoya University).

Year	Earthquake/tsunami	M	Area
684	Tennmu earthquake/tsunami	M<8.25	Nankai Trough
869	Jyogan earthquake/tsunami	M8.5	East Japan
887	Ninna earthquake/tsunami	M8–8.5	Nankai Trough
1498	Meio earthquake/tsunami	M8.2–8.4	Nankai Trough
1596	Keicho-Bungo earthquake	M7.0	Nankai Trough
1611	Keicho Sanriku earthquake/tsunami	M8.1	East Japan
1707	Hoei earthquake/tsunami	M8.6	Nankai Trough
1703	Genroku Edo earthquake	M7.9–8.2	Kanto Area
1771	Yaeyama earthquake/tsunami	M7.4	Ryukyu Trough
1854	Ansei earthquake/tsunami	M8.4	Nankai Trough
1896	Meiji-Sanriku earthquake/tsunami	M8.2	East Japan
1923	Kanto earthquake	M7.9	Kanto Area
1933	Showa Sanriku earthquake/tsunami	M8.1	East Japan
1944	Showa Tonankaki earthquake/tsunami	M8.0	Nankai Trough
1946	Showa Nankai earthquake/tsunami	M8.1	Nankai Trough
1968	Off Tokachi earthquake/tsunami	M7.9	East Japan
1983	Central Sea of Japan earthquake/tsunami	M7.7	Sea of Japan
1993	Hokkaido-Nansei-oki earthquake/tsunami	M7.8	Sea of Japan
2011	East Japan	M9.0	East Japan

After SSJ chronological scientific table, excerpt.

Table 2.
Historical tsunami in Japan.

At the Sumatra 2004 earthquake and tsunami, they had 200,000 deaths. One of the coastal cities in Indonesia damaged by the tsunami is shown in **Figure 2**. At the 2011 Great East Japan earthquake, 20,000 died or got missing in the tsunami. One of the damaged cities along the coast and the destroyed bank of Kitakami River are shown in **Figure 3**.

From the lessons learned from historical earthquakes and tsunamis, restorations take a long time for severely damaged areas with large numbers of victims. In particular, in coastal cities and places where large numbers of people are impacted by

Figure 2.
Damage by 2004 Sumatra tsunamis (after the Ministry of Foreign Affairs in Japan).

large tsunamis, the restoration of cities and communities must first involve evacuation and then recovery as per the plans for reconstructing cities, and the recovery of damaged cities confront each other because of different opinions and methods; therefore, it takes a long time to reach consensus.

We must discuss restoration from many points of view, such as those of safety, resilient and cozy cities, scenarios of the recurrence of natural disasters, economics, communities, legality, human resource cultivation, the future, and so on. For restoration, at first, we must reconstruct buildings and cities. In the process of reconstruction, cities must approach representatives from engineering, scientific, and legal fields for newly constructed cities and communities.

Thanks to engineering, earthquake-resistant structured buildings will increase, the reconstruction of breakwaters will advance, and liquefaction damages will be reduced compared to that of the present. Further, research on earthquakes and tsunamis will progress, thanks to lessons learned from disasters of earthquakes and tsunamis.

However, the restoration of the coastal area is halfway down the road to recovery from the catastrophic damages in the 2011 East Japan earthquake/tsunami.

Therefore, what are essential and indispensable for us are engineering, scientific and medical fields, as well as social science fields, such as sustainable economics, the mental recovery of people in damaged areas, sustainable communities, disaster mitigation education for communities, and plans for future regions, cities, and countries for many generations.

In addition, the agriculture and fishery industries, so-called primary industries, hold the key to the rapid recovery from natural disasters and reconstruction.

I will discuss later the integration of these fields, "resilience science," as a disaster mitigation science which is indispensable for the bright future in damaged areas and its rapid restoration.

1.2 Disaster mitigation countermeasures in coastal area for tsunamis and earthquakes

How can we reduce the damage caused by a tsunami or an earthquake? Many different measures are being implemented in each field. Among them, scenarios for tsunami and earthquake and the explicit danger based on scientific research must be the top priority.

For instance, for the Nankai Trough megathrust earthquake, **Figure 4** shows the simulation of tsunami propagation and inundation from the Nankai Trough in Southwest Japan to the coastal region.

Figure 3.
Damages by 2011 East Japan earthquake. (Above) Damaged Onagawa city in Miyagi Prefecture (after associate professor Sakamoto of Nagoya University). (Middle) Damaged Otsuchi city in Iwate Prefecture (after Mr. Satoshi Nagao). (Below) Damaged Kitakami River in Iwate Prefecture (after associate professor Sakamoto of Nagoya University).

By examining this simulation based on a recurrence scenario, it is possible to imagine the expected damages of the coastal region and think of the effective countermeasures.

Experimental research is also as important as the simulation research, and it is possible not only to validate the expected damage but to verify the simulation.

As I have already introduced previously in the other publication, "Many tsunami researchers have inspected the damage of the 2004 Sumatra earthquake and tsunami and the 2011 East Japan earthquake and tsunami using field surveys and simulations.

In **Figure 5**, a tsunami simulation for Kesennuma, Miyagi Prefecture used the actual damage done in the 2011 East Japan earthquake and tsunami. **Figure 6**

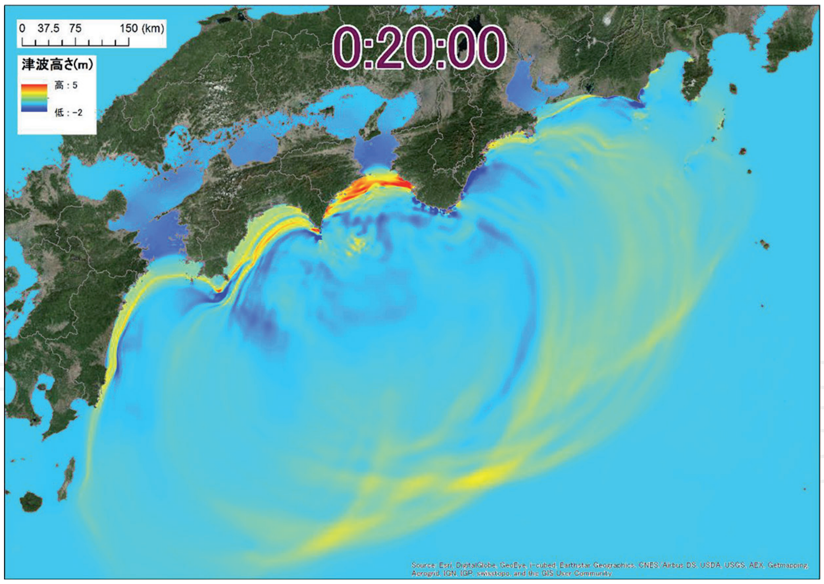

Figure 4.
Tsunami simulation around the Nankai Trough (after Prof. T. Baba University of Tokushima).

indicates how the sediment behavior in the city of Rikuzen-Takata, Iwate Prefecture would affect the environment on the shoreline and offshore around the bay" [3].

The behavior of sediments on-and offshore occurred due to environmental changes, such as damages to agriculture due to salt water and damages to fishery due to changes in nutrients.

Restoration and revival in coastal areas will be delayed more due to environmental damages and changes.

"Of course, before the tsunami struck the coastal area, strong motion and a long-period seismic wave from the huge earthquake will cause damage such as the collapse of buildings (**Figure 7**), liquefaction (**Figure 8**) and fires (**Figure 9**)" [3].

Measures to prevent liquefaction before the earthquake are very important as the recovery is very difficult for damage due to liquefaction. Different types of damages in local areas like subsidence and elevation can be expected.

When a massive earthquake occurs, compound damages will be caused (**Figure 10**), and comparing to other ordinal sizes of earthquake, the restoration and revival can be delayed for much longer time.

Thus, we can say that the preparation of a city restoration plan and its revival plan are urgent matters in a coastal region.

"**Figure 11** indicates the process of restoration in Kesennuma, Miyagi Prefecture after the 2011 East Japan tsunami and earthquake. From **Figure 11**, we can understand that restoration is not always rapid. Due to the severe damage in many areas of East Japan the restoration has been slow" [3].

Natural disasters occur anytime and anywhere; recently, in 2015 in Nepal, M7.8 of destructive earthquake occurred. With that event, internationally it was recognized that the spread of disaster knowledge, rapid rescue, well-organized countermeasures, and restoration plans are very essential and significant issues in the case of such huge natural disasters.

In 2016, a destructive earthquake occurred in Kumamoto Prefecture with multiple shocks that generated huge seismic waves, which caused additional damages.

Recently, multinatural disasters occurred in Indonesia such as 2018 Lombok Island earthquake, 2018 Sulawesi Island earthquake/tsunami, and 2018 Anak Krakatau volcano eruption and tsunami, which generated many victims (**Figures 12** and **13**).

To revitalize communities in coastal areas damaged by tsunamis and earthquakes, we must promote sustainable economic activity, training of human

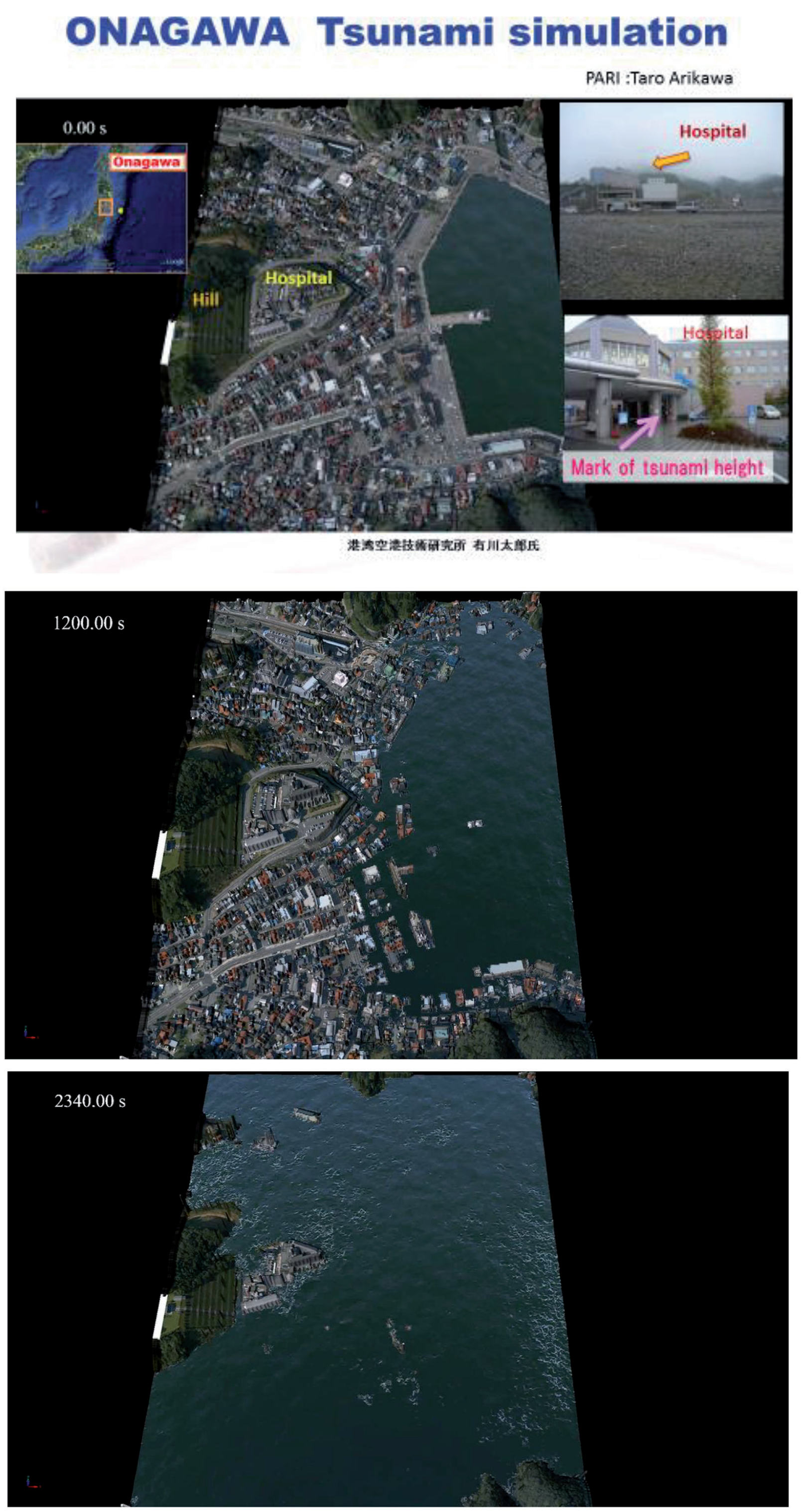

Figure 5.
Simulated tsunami damage at Onagawa city by 2011 East Japan earthquakes (after Prof. Arikawa Chuo University).

resources, and environmental control innovations in technology and local characteristics.

For example, in Sendai regions seriously damaged by the East Japan earthquake and tsunami in 2011, some people and communities started to turn the troubles to their advantages by cultivating salty tomatoes or using hydroponic culture.

Through an intervention of a Japan International Cooperation Agency (JICA) project (**Figure 14**) between Banda Aceh, Indonesia, damaged by the Sumatra earthquake in 2004 and tsunami, and Higashimatsuyama, Sendai, Japan, damaged by the East Japan earthquake in 2011, great mutual empowerment and cooperation have been ongoing.

Figure 6.
The sediments behavior of Rikuzen-Takata city of Iwate Prefecture in Tohoku district by the East Japan earthquake (after Prof. Takahashi Kansai University).

Figure 15 shows a model of empowerment. Empowerment means the act of conferring legality or sanction or a formal warrant and procuring power even in disadvantageous situations.

In Japan and many other countries, destructive natural disasters such as earthquakes, tsunamis, volcanic eruptions, and floods occur, but damage reduction measures are insufficient, and recovery is not always rapid and resilient.

For damage reduction and resilient recovery, we must construct and push resilience science and disaster mitigation forward. Resilience science will be explained in the next section.

Figure 7.
Collapses of buildings in Kobe at 1995 Kobe earthquake (after Kobe damage database).

Figure 8.
Liquefaction damage in Chiba Prefecture at East Japan (after Funabashi city data in Chiba Prefecture).

1.3 Resilience science as disaster mitigation science

Resilience science and disaster mitigation science are synthetic sciences. These sciences are based on multiple disciplines and fundamental and advanced research fields.

These research fields are significant and important at each stage, such as before, during, and after the natural disaster.

In the context of disaster mitigation, I would like to propose the concept of resilience science and disaster mitigation science (**Figure 16**).

We define disaster mitigation science as follows:

Disaster science includes science, civil engineering, medical science, and social science.

Science includes many research fields, such as geophysics with seismology, geology, volcanology, meteorology, physics, mathematics, hydrodynamics, etc.

For understanding and elucidating the mechanisms of earthquakes, tsunamis, heavy rains, and other natural hazards, these research fields are quite fundamentally important and significant. Based on research fields, we can provide some scenarios of natural hazard occurrences such as earthquakes, tsunamis, and so on. Therefore, scenarios from science are very useful for the planning and preparation of countermeasures.

Many researches on the utilization of big data with real-time data have focused on disaster mitigation and restoration, especially for earthquakes, tsunamis, heavy rains, etc.

a

b

Figure 9.
Fire damage at (a) 1995 Kobe earthquake (after Kobe database), (b) fire damage at 2011 East Japan earthquake (after JGSDF—Japan Ground Self-Defence Force).

Then, we discuss about engineering fields. There are many research fields such as architecture and civil engineering fields within structural design, structural mechanics, geotechnics, computer science with IT/AI, earthquake resistance structure and isolating countermeasures, tsunami and river engineering, etc. These engineering fields and technologies involve IT/AI, and countermeasures, finally, can lead to proper/rapid disaster mitigation for infrastructure and individual buildings, etc.

As real-time monitoring systems, many observatories for early warning of earthquakes and tsunamis will be developed and deployed offshore, for instance, DONET and S-NET in Japan, MACHO in Taiwan, NEPTUNE in Canada, etc.

For disaster mitigation, many technologies in engineering fields are mainly focusing on countermeasures with hardware and software.

Actually, the reasons why only these fields and technologies in science, engineering, and medicine would be insufficient for disaster mitigation, restoration, and revival are that evacuation drills, education, reconstruction of communities damaged by natural hazard, and the mental health care of victims also require social science approaches.

In social sciences, there are many research fields, such as sociology, pedagogy, economics, medicine, informatics, psychology, public administration and politics,

Figure 10.
Compound disaster

philosophy, and others. For instance, public administration or politics or law is justly deemed indispensable.

Moreover, pedagogy is very fundamentally important for disaster education and human resource development. It must be the ultimate countermeasure for disaster mitigation [4] against future natural disasters.

It is indispensable for disaster mitigation and for science, engineering, medicine, and social sciences in societal resilience and evolution. It is also needed in each field for continuous evolution and bright future.

To achieve disaster mitigation, restoration, and revival, collaboration and integration of the different fields, which are also needed in resilience science, will be conducted. The human resource cultivation must be the final countermeasure for societal resilience and evolution [5].

Again, I would like to propose the objectives of resilience science as shown in **Figure 16**, including the following details from (1) to (14) which I have already introduced before in the other publication [3]:

1. **Science:** Studying natural disaster scenarios, risk, and human resources development.

2. **Engineering:** Developing technology on measures, restoration correspondence, damage reduction, and quick restoration of community.

3. **Medical care:** Conducting disaster medical care, including methods for medical treatment and measures for health promotion.

4. **Agriculture/fisheries:** Studying measures to restore agriculture and marine products for local revival and reconstruction after a disaster.

5. **Sociology:** Investigating social disaster correspondence as it had occurred in the past and suggesting future social routes and disaster correspondence.

DOI: http://dx.doi.org/10.5772/intechopen.85329

Figure 11.
Restoration of Kesennuma City of Miyagi Prefecture in Tohoku district during 4 years (after associate professor M. Sakamoto of Nagoya University).

6. **Economics:** Developing damage reduction predictions and construction of a hybrid decreasing disaster economic system over a wide area supply chain and with a local supply based on damage predictions and creating an industry that resists disasters like that of business continuity plan (BCP)/data continuity plan (DCP).

7. **Geography:** Examining disaster geographical feature studies (local walks, virtual town walks using aerial photograph, satellite photos, and so on).

8. **Informatics:** Using disaster information systems (use of ICT and AI) and human science.

9. **Public administration and politics:** Exploring administration and politics for a society resilience against disasters.

10. **Literature/philosophy:** Exploring literature for information archives, communication techniques, and future hearsay technology. In philosophical education, people learn to think by themselves, to make judgments by themselves, and to act properly by themselves. Finally, philosophical education cultivates human resources.

11. **Art:** Healing damaged people and communities, carrying unambiguous information, and archiving the damage.

12. **Law:** Examining resilience law for effective legal action and examination of extralegal measures for revival plans.

13. **Psychology:** Applying research on communication and psychological effects between transmitters and recipients.

14. **Pedagogy:** Promoting human resource development for the leaders of disaster mitigation science.

This resilience science focuses on rapid rescue, disaster mitigation, rapid recovery, and cultivation of human resources.

Figure 12.
Indonesia Sulawesi Island earthquake and tsunami damage (after Reuters/Aflo).

Figure 13.
Indonesia Anak Krakatau volcano. The eruption of this volcano generated tsunami (after Reuters/Aflo).

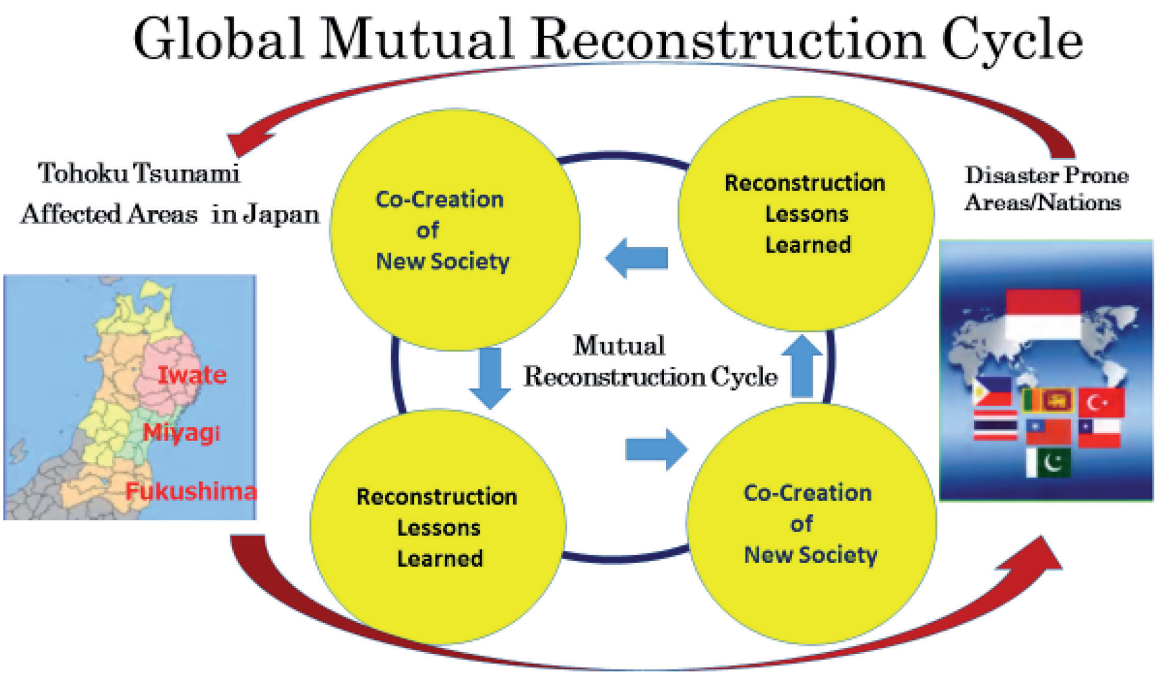

Figure 14.
Empowerment model in JICA project.

The cultivation of human resources is most important for disaster mitigation against many kinds of hazards.

We will expand the concept of resilience science to countries that are prone to natural disasters [6].

Recently, according to the global warming, huge storm and flood occurred frequently in the world. Therefore, the compound natural disasters such as the earthquake, tsunami, volcanic eruption, storm, and flood within a short term might have been supposed easily. So, we have to consider the compound disasters for disaster mitigation and resilient society.

1.4 Resilient society

For the realization of a resilient society, a continuity plan (CP) is indispensable. Varieties of continuity plan (CP) are defined below:

1. Personal continuity plan (PCP)

2. Family continuity plan (FCP)

3. Community continuity plan (CCP): BCP + DCP + Mentality

4. National continuity plan (NCP)

5. Asian continuity plan (ACP)

6. International continuity plan (ICP)

After natural disasters, individuals and families are damaged mentally, economically, and environmentally.
As a result, people and families move to new areas.

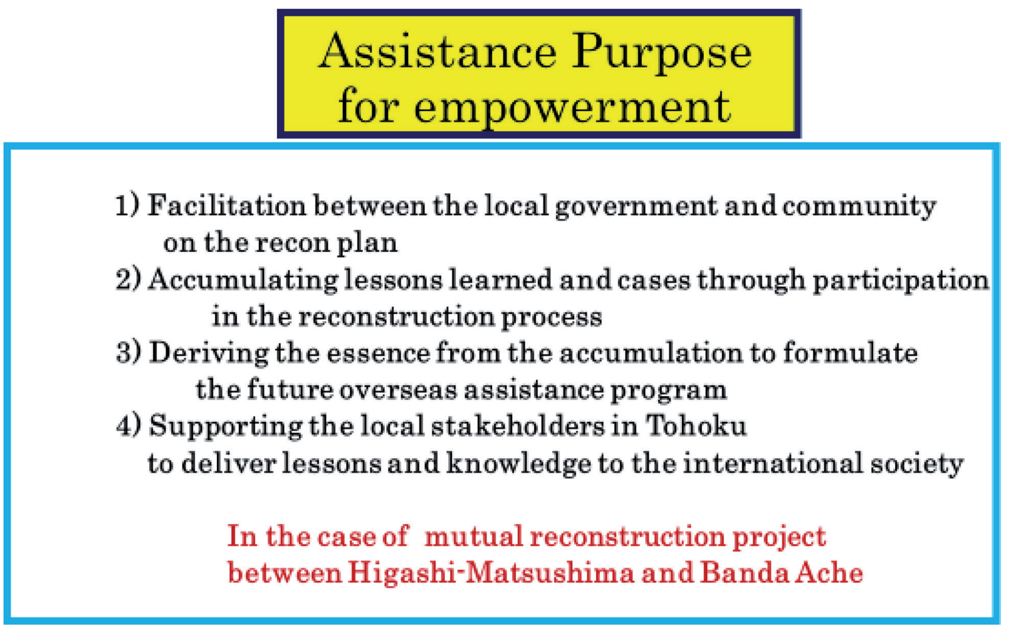

Figure 15.
Assistance purpose (after JICA).

Figure 16.
Disaster mitigation science.

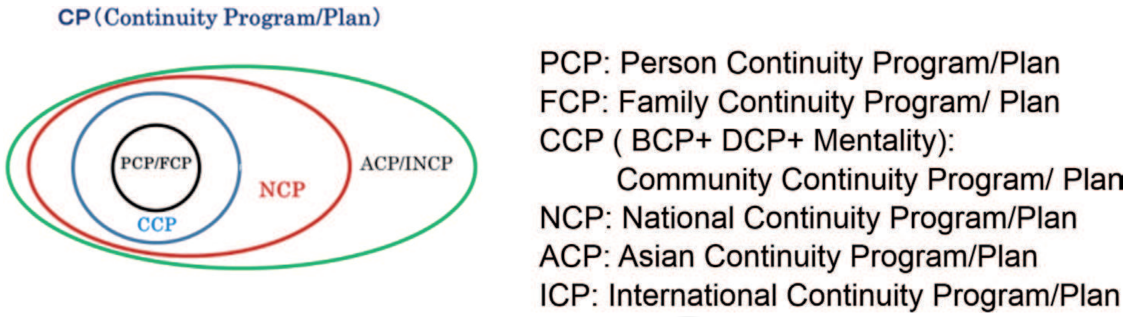

Figure 17.
Continuity program/plan.

Therefore, PCPs and FCPs are important for the protection of individuals and families from being broken and disappointed.

CCPs are indispensable for the resilient society and bright future. CCP is a CP that includes BCP and DCP, which utilize regional strengths such as resilient human resources, environment, culture, industry, and community.

In a more expanded concept of CP, NCP, ACP, and ICP focus on a national, Asian, and international continuity plans (CP) (**Figure 17**). Natural disasters are occurring in anywhere without boundaries. This is the reason why that we propose the expanded concept of CP.

Finally, to hedge against social issues in the near future, such as depopulation, aging, and huge natural disasters, resilience science and disaster mitigation science must include cultivating academia, industries, and culture as indispensable concepts and measures for a resilient society [7].

For individuals, families, local communities, the nation, Asia, and the world and finally the bright future, we must construct and realize a resilient society.

2. Conclusion

Recently, many natural disasters generated severe damages in the world. After these natural disaster damages, many people worked frantically for rescues, recoveries, and future societies.

Actually, they are excellent and respective activities. However, the extent of progress is no always speedy in recoveries and reconstructions especially. So, we recognize that pre-reconstruction plans and human resource cultivation are significant and important.

The lessons learned from 2011 East Japan earthquake are as follows:

1. Rapid evacuation from tsunami
2. Countermeasures against tsunami
3. Necessity of safety evacuation places and buildings
4. Bonds with family and community
5. Speedy recoveries and reconstructions
6. Necessity of pre-reconstruction plans

Especially, for the future society, speedy recoveries and reconstructions and pre-reconstruction plans are very important and indispensable.

Therefore, we propose the resilience science for resilient society.

The resilience science has multidisciplinary fields based on human resource cultivation for resilient society, which will lead to a bright future. Finally, against destructive natural disasters, we have to progress resilience science furthermore.

IntechOpen

Author details

Yoshiyuki Kaneda
Institute of Education, Research and Regional Cooperation for Crisis Management Shikoku (IECMS), Kagawa University, Takamatsu City, Kagawa, Japan

*Address all correspondence to: kanedaykg@cc.kagawa-u.ac.jp

References

[1] Vogel C, Moser S, Kasperson R, Dabelko G. Linking vulnerability, adaptation, and resilience science to practice: Pathways, players, and partnerships. Global Environmental Change. 2007;**17**:349-364

[2] Olsson L, Jerneck A, Thoren H, Persson J, O'Byrne D. Why resilience is unappealing to social science: Theoretical and empirical investigations of the scientific use of resilience. Science Advances. 2015;**1**(4):1-11

[3] Kaneda Y. Resilience science for a resilience society in seismogenic and tsunamigenic countries. Journal of Disaster Research. 2017;**12**(4):719-720

[4] Sakamoto M, Kaneda Y, Kumamoto K, Tanircan G, Puskulcu S. The comparative study on the disaster preparedness and evacuation behavior of school children in Turkey and Japan. In: Abstract of European Geosciences Union (EGU); 12-17 April 2015; Vienna, Austria; 2015

[5] Kaneda Y, Shiraki W, Tokozakura E. Toward to disaster mitigation science—Research on the Nankai Trough seismogenic zone. In: Abstract of European Geosciences Union (EGU); 12-17 April 2015; Vienna, Austria; 2015

[6] Porter K, Beck J, Shaikhutdinov R, Au S, Mizukoshi K, Miyamura M, et al. Effect of seismic risk on lifetime property value. Earthquake Spectra. 2004;**20**(4):1211-1237. http://www.sparisk.com/pubs/Porter-2004-LPV.pdf

[7] California Seismic Safety Commission. Earthquake Risk Management: Mitigation Success Stories. SSC Report No. 99-05; 1999