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Overview of the 2011 East Japan Earthquake and Tsunami Disaster

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Areal extent of affected area, their multiple damage by the 2011 East Japan Disaster is presented, including crisis of nuclear accident and extensive activities for help from the world.

1. Preface

On JST 2:46 pm, March 11, 2011, a mega earthquake with Richter scale of magnitude 9.0 struck off the Pacific coast of east Japan which shook much part of east Japan with the JMA Seismic Intensity of 6 or more; then large tsunami arrived at the coast of the Pacific several times. USGS reported that "this magnitude places the earthquake as the fourth largest in the world since 1900 and the largest in Japan since modern instrumental recordings began 130 years ago."★1

It was one of the most intense natural phenomena in Japan's history. Owing to the phenomena, Japan has faced severe damages in unprecedented vast area at once. It was definitely a "millennium" class disaster in Japan because not only of its severity, but also of its areal extent where appeared every type of expected disasters in earthquake and tsunami.

In this beginning chapter, an overview of the disastrous phenomena and an outline of resulted damages will be described, hoping the readers across the world to know about the situation in the Pacific coast of east Japan and how it had been.

2. Earthquake, tsunami and the extent of affected area

Power of the East Japan Earthquake can be grasped firstly by the spatial distribution of seismic intensity reported by Japan Meteorological Agency (JMA) shown in Fig.1. In JMA's Seismic Intensity, grade of 5+ and over are assumed to have damages for houses and infrastructures.★2 In the East Japan Earthquake, grade 5+ and more were measured in vast areas in the Pacific side of the eastern half of Honshu Island, of which maximum intensity observed was grade 7 at the northern part of Miyagi Prefecture. Just after the earthquake, "tsunami alert" for the entire Pacific coast and "major tsunami alert" with expected height was 3～6m were announced for eastern Honshu (Fig.2). But actually tsunami reached far higher (Fig.3) and deeper to inland area than any existed expectations and experiences, resulted in the unprecedented severe inundation mainly in the Pacific coastline of eastern Honshu Island.

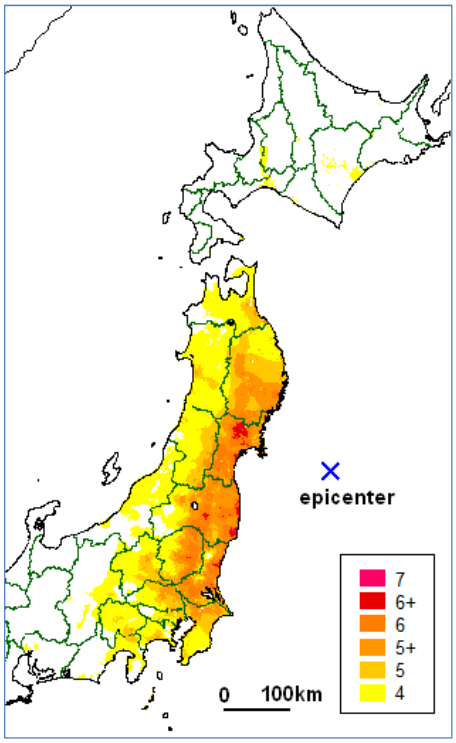


Fig.1 JMA Scale (Shindo)

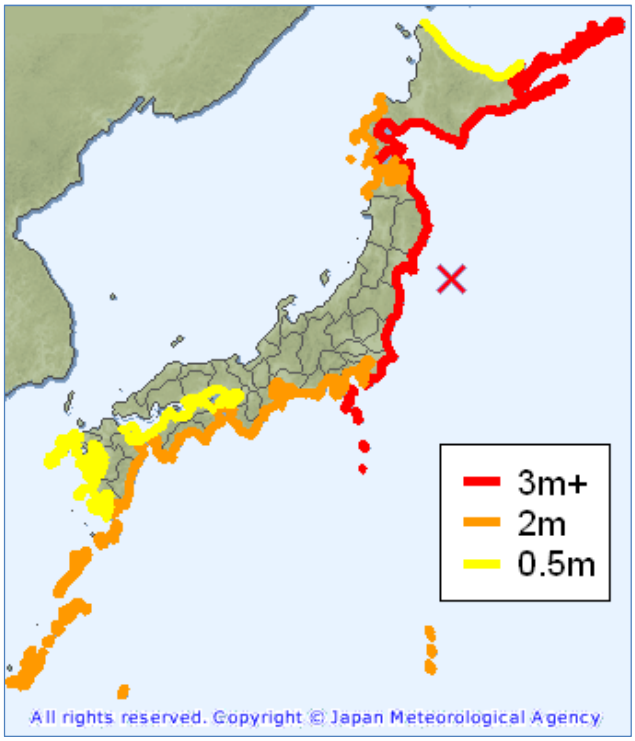


Fig 2 Alerted tsunami height

Source: Japan Meteorological Agency (rewritten by the author)

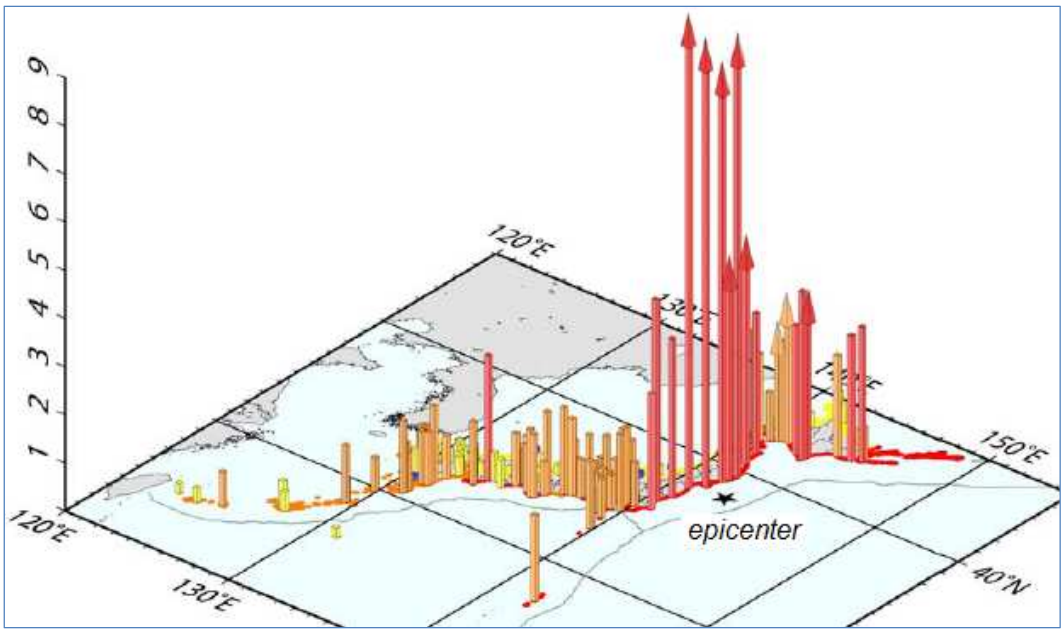


Fig.3 Tsunami height felt at various observation points

Columns with vertical arrow indicate the case where the observation facility was broken by the first wave, and higher wave could be expected to come afterwards. Source: Japan Meteorological Agency.

Such catastrophic phenomena caused enormous damage especially in the Pacific coast of eastern Honshu, and extensive related influence in whole Japan and the world. One of the most remarkable specialties of the March 11 Earthquake and Tsunami disaster should be such "**extensiveness**" of the damaged area. The phenomena inevitably caused a series of expected of disasters depending on the local conditions as shown in Table 1. Such "**complexity** "of the multiple damages should be the next distinctiveness of the disaster.

Table 1 Types of the disasters appeared

whole area	blackout interruption of telephone call interruption of traffic damage to structures
inland area *by earthquake*	landslide, ground failure reservoir collapsing
coastal area *mainly by tsunami*	inundation, flowing out severe damage to infrastructure fire in port area destruction of coastal forests
alluvial plain	liquefaction
major city	"commuter refugee"

3. Human and housing damage

The East Japan Earthquake and Tsunami caused complex of disasters is known to have followed by about 470,000 individuals evacuated in maximum (as of March 13), 19,824 death or missing persons, and 300,400 totally or severely damaged houses (both as of October 11). These numbers were enough rated as one of the second largest disasters in Japan's modern history, followed Kanto great earthquake disaster in 1923 (Table 2).

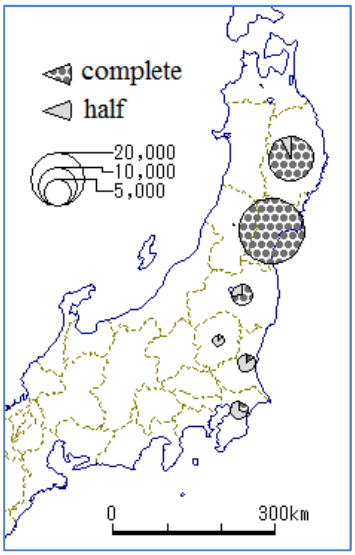
Table 2 Major earthquake in Japan after modern age

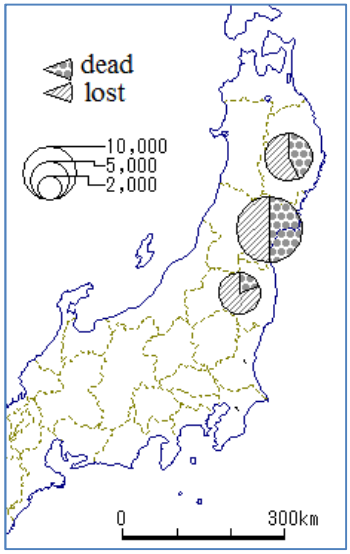
year	month	name	power (M)	houses destroyed		lost people
				entirely	half	
1891	Oct	Nobi	8.0	142,177		7,273
1896	June	**Sanriku**	**8.5**	**11,700**		**21,959**
1923	Sept	**Kanto**	**7.9**	**109,713**	**102,773**	**105,385**
1933	Mar	Sanriku	8.1	11,894		3,064
1944	Dec	Eastern South	7.9	35,000	60,000	1,223
1945	Jan	Mikawa	6.8	7,221	16,555	2,306
1946	Dec	South	8.0	35,000		1,330
1948	June	Fukui	7.1	36,184	11,816	3,769
1995	Jan	**Southern Hyogo**	**7.3**	**689,776**		**6,433**
2004	Oct	Chuetsu	6.8	3,175		68
2011	Mar	**East Japan**	**9.0**	**304,000**		**19,824**

Source : Chronological Science Table（理科年表）etc.

The damages were so devastating and widespread that the total damage is unsettled. Some municipalities are still counting the number of casualties and missing persons. But some maps of

human and housing damages three weeks after the Earthquake and Tsunami can give us a enough information as for where the most severely affected area was (Fig.4~6). These figures are showing that damages appeared predominantly in the Pacific side of northeastern Honshu Island including three prefectures of Iwate, Miyagi, Fukushima, which obviously tell us the third distinctive characteristics of the disaster is the disaster caused huge tsunami followed earthquake.





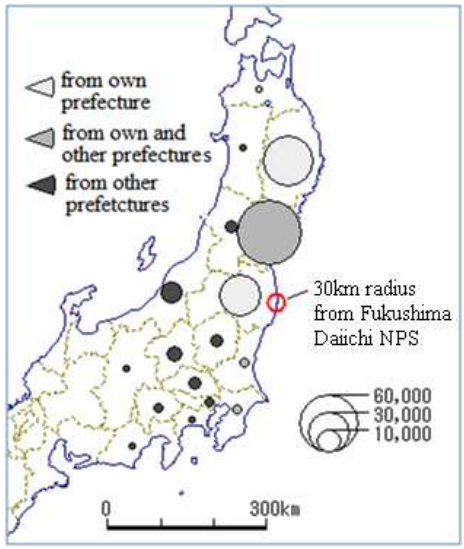


Fig.4 houses destroyed Fig.5 Casualties Fig.6 Evacuee

data : National Police Agency, April 1, 2011 "NPS" indicates "Nuclear Power Station".

Such characteristics of the disaster are more clearly shown in Fig.7 depicted by more local scale with identifiable municipality, using the name lists issued by prefecture or prefectural police of these three prefectures. The figure indicates most of the victims were found in municipalities along the Pacific coast.★3

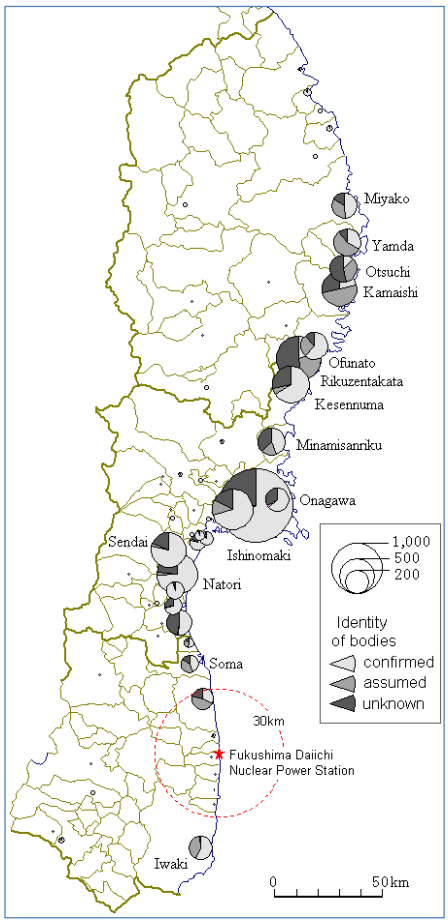


Fig.7 Casualties (March 29)

4. Nuclear Accident

As appeared in Fig. 6 and 7 in advance, the accident of nuclear power plants was another shocking disastrous event, which had given continuing impacts not only nationwide but also worldwide. It was caused by the unexpected height of tsunami which flooded the Fukushima Daiichi Nuclear Power Station located approximately 200km north of Tokyo and 100km south of Sendai about one hour after the earthquake It followed a series of critical events that all emergency power generators were halted by flooded seawater, and all

cooling functions of nuclear reactors were broken, resulted in severe crisis of meltdown of nuclear fuels, explosions of the plant buildings, and leakage of radioactive matters to the environment. The monitoring of the radioactivity revealed a distribution of pollution and the densely contaminated area near the Station and northeastern area from it (Fig.8).

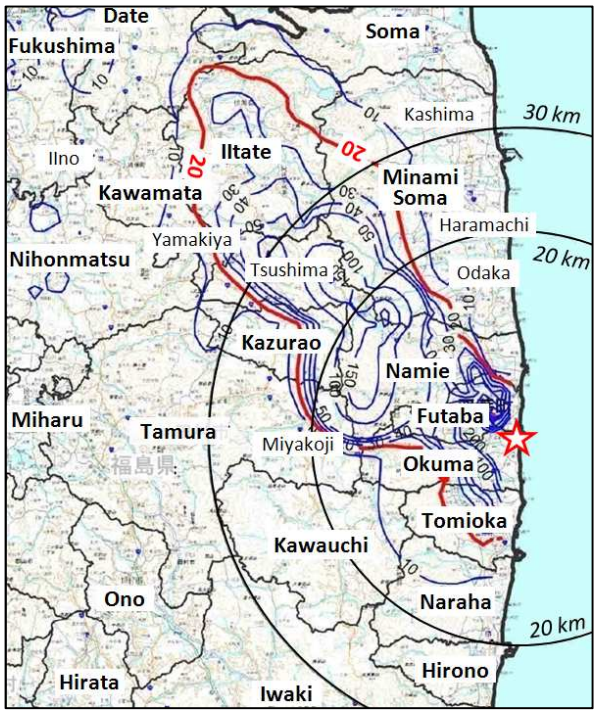


Fig.8 Yearly accumulative dose (mSv) estimated by field monitoring from March 11 to April 21

☆ : Fukushima Daiichi Nuclear Power Station

source : http://www.mext.go.jp (rewritten by the author)

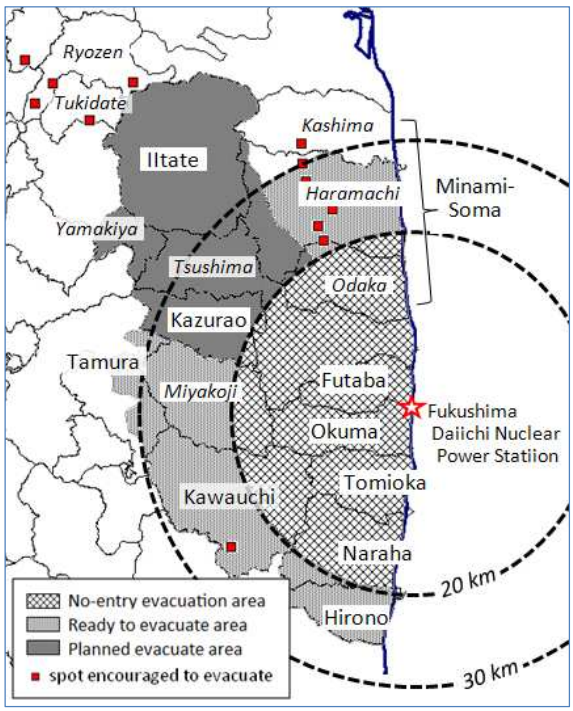


Fig.9 Evacuation area around the Fukushima Daiichi Nuclear Power Station

source : http://www.gsi.go.jp/common/000060521.pdf

(rewritten by the author)

All residents within 20 km radius and much of residents between 20~30 km radius from the station were forced to evacuate outside the radius. Therefore, most of evacuee from other prefecture shown in Fig.6 indicates people escaping from the polluted area to other prefectures.

The Fukushima nuclear crisis was followed by the evacuation order by national government.★4 By April 21, the area where every inhabitants should be forced or encouraged to evacuate were designated, and on June 30, several spots were designated as the place encouraged to evacuate. These designation are shown in Fig.9. Inside of 20km radius, no body could enter freely and the retrieval and confirmation of bodies were delayed.

Such unexpected events plunged the region in critical situation, as well as declined the confidence in nuclear power technology in the world. Though a designation of ”ready to evacuated area” with safety level of pollution was canceled after October, 2011, least inhabitant have returned there.★5 It may take far longer years than we assume now for the region to recover actually.

5. Damages for infrastructure

By the East Japan Earthquake and Tsunami and some of aftershocks, much of structures for people's everyday lives, public services and industries in eastern Honshu had enormous damages. The cabinet office estimates the total value of the damages reach 16,900 billion yen except for the nuclear accident related damage. Its outline is shown in Table 3.

Table 3 Damaged value (billion yen) estimated by the Cabinet Office (June, 24, 2011)

contents		damaged value
structures for living and industry	houses, shops, factories, installed mashinaries etc.	10,400
lifelines	water, gass, electricity, telecommunication related facilities	1,300
public infrastructures	transportation, drainage, river related structure	2,200
primary industry	agriculture, forestry, fishery related structures	1,900
others	education, welfare, medical, waste treatment related structures	1,100
Total		16,900

source : http://www.bousai.go.jp/oshirase/h23/110624-1kisya.pdf

After the earthquake, power cut was happened in vast area of Tohoku and eastern Kanto. Total number of households lost electricity reached 4.4 million in Tohoku, and 4.05million in Kanto area just after the disaster. Although many of them were recovered in few days except for the severely destroyed coastal area by tsunami, restriction for the power supply was continued until end of summer, 2011.

As for the transportation structures, many cracks and bumps appeared in national roads and highways in Kanto and Tohoku area. Especially, in national route 45 running along the Pacific coast of Tohoku, 69 sections were closed owing to the severe damages including bridge falls. Sinkansen got damages in 1,200 spots by the main quake on March 11 and in 550 spots by the most powerful aftershocks on April 7. Though the arterial routes recovered their minimum functions in few days, there remains broken railroads in the coastal area severely destroyed by tsunami.

Almost every port located in the Pacific coast in eastern Kanto and Tohoku stopped its operation, owing to land subsidence, floating and deposited debris, and severe damages on loading facilities, wharfs and seawalls. Just after the tsunami, Aomori was the only available port. Many of the main transportation related infrastructures were recovered, but as for Sanriku coast, many of the fishing ports and some railroad lines have not recovered even now (as of March, 2012).

Vast damages on the transportation structure caused the disruption of distribution systems or the so-called "logistics" in the Pacific side of eastern Honshu, resulting extreme shortage of the necessary commodities there. Especially shortage of the oil was a emergent problem to help the damaged area. To solve such challenged situation quickly, national government took a tactics named "skewer teeth", where the inland vertical artery was recovered at first, then some horizontal routes accessible to the severely damaged coastal area were opened. In addition, oils were carried

by tank trains using the passable railroad along the Japan Sea.

As for the telecommunication, telephone services including mobile phone were disrupted in vast area in eastern Honshu, owing to physical destruction of the facilities in tsunami affected area, and emergency control operated by the telecom companies. In such situation, internet services relatively kept availability in the area basic infrastructure could escape from severe damage. It proved that internet could play a important role in a critical situation of disaster.

7. Damages for industries

1) private companies

Above mentioned enormous damages gave significant influence on the various industrial activities in the affected area. According to a survey conducted just after the earthquake by the Teikoku Data Bank Co.(TDB), one of the leading survey company for the activities of private enterprises, most of private companies in Japan got damage from the disaster irrespective of the region, but in eastern Honshu including Tohoku and Kanto ratio of the damaged companies reached more than 80% (Table 4).

Table 4 Influence to the private companies

	damaged		no damage		unknown		total	
Hokkaido	413	*71.3*	50	*8.6*	116	*20.0*	579	*100*
Tohoku	**392**	***84.5***	**23**	***5.0***	**49**	***10.6***	**464**	***100***
North Kanto	**518**	***81.8***	**41**	***6.5***	**74**	***11.7***	**633**	***100***
South Kanto	**2,957**	***82.4***	**218**	***6.1***	**414**	***11.5***	**3,589**	***100***
Hokuriku	425	*77.0*	43	*7.8*	84	*15.2*	552	*100*
Tokai	947	*78.9*	79	*6.6*	175	*14.6*	1,201	*100*
Kinki	1,392	*75.6*	136	*7.4*	313	*17.0*	1,841	*100*
Chugoku	494	*72.1*	60	*8.8*	131	*19.1*	685	*100*
Shikoku	251	*71.5*	46	*13.1*	54	*15.4*	351	*100*
Kyushu	579	*68.0*	84	*9.9*	189	*22.2*	852	*100*
Japan Total	8,368	*77.9*	780	*7.3*	1,599	*14.9*	10,747	*100*

survey conducted by Teikoku Data Bank Co. from March 23 to 31, 2011
source : http://www.tdb.co.jp/report/watching/press/pdf/keiki_w1103.pdf

TDB published a result of another filed survey conducted on June, 2011, reporting that 2,070 companies which was about 40% of the total in tsunami affected coastal area of Tohoku remained shut down, including 1,632 of lost companies shown by “unable to interview” in Table 5.

Those results show severe situation of the private companies in tsunami affected costal area in Tohoku.

Table 5 Situation of companies in coastal area of Tohoku

	number of reply	
hoping to reopen	2,360	*55.1*
under consideration	226	*5.3*
thinking to close	62	*1.4*
unable to interview	1,632	*38.1*
total	4,280	*100*

http://www.tdb.co.jp/report/watching/press/pdf/

2）Primary industries

Primary industries also suffered from significant damage especially in the tsunami affected coastal area in Tohoku. As for the fishery, almost all fishing ports and facilities of aquaculture there were severely devastated by the earthquake and following tsunami (Table 6). The fishery service industries including fish markets, ice makers, cold storages, boat repairing docks, fishermen's rest houses, shipping agents, and marine products processing factories located at major fishing ports such as Miyako, Kesennuma, Onagawa, and Ishinomaki were mostly destroyed if not flooded away.

Table 6 Damages for fishing ports and fishing boats

	fishing ports			fishing boats		
		damaged ports	lost value (million yen)	registered boats	damaged or lost	lost value (million yen)
Hokkaido	282	12	1,259	16,293	793	8,723
Aomori	92	18	4,617	6,990	620	11,396
Iwate	111	108	285,963	10,522	9,673	23,367
Miyagi	142	142	424,286	13,570	12,023	112,900
Fukusima	10	10	61,593	1,068	873	6,639
Ibaraki	24	16	43,118	1,215	488	4,363
Chiba	69	13	2,204	5,640	405	851
Total	730	319	823,040	55,298	24,875	168,239

source :http://www.jfa.maff.go.jp/j/press/kikaku/pdf/110628-02.pdf（水産復興マスタープラン）

Damages for agriculture was predominant in Miyagi Prefecture as shown in Table 7, where tsunami running up to 5km from the coast line, flooding way entire coastal settlements and carrying debris with sea water over the fertile paddy fields.

Redevelopment plan for the integration of port facilities into selected fishing ports and the conversion to intensive agriculture have been carried into action.

Table 7 Estimated flooded area (ha) of the cultivated land

	cultivated land	flooded area	%
Aomori	156,800	79	0.05
Iwate	153,900	1,838	1.19
Miyagi	136,300	15,002	11.01
Fukushima	149,900	5,923	3.95
Ibaraki	175,200	531	0.30
Chiba	128,800	227	0.18
total	900,900	23,600	2.62

http://www.maff.go.jp/j/tokei/saigai/pdf/shinsai.pdf

3）Tourist business

Tourist business suffered significantly from not only the direct damage of earthquake and tsunami, but also the indirect damage of nuclear accident. In Iwate Prefecture, the number of cancellations of hotels or inns reached 240

thousands, and in Fukushima Prefecture it reached 680 thousands during one month after the disaster.. According to Japan Tourist Agency, cancellation reached 170 thousands even in the area other than Tohoku and Kanto during same period.★6

Tourists from foreign countries also sharply decreased after the disaster. On March 2011 the number of foreign tourists reduced by half in comparison with the same month of the previous year. Though it has gradually recovered, still stays in the level less than previous year (Fig.10).

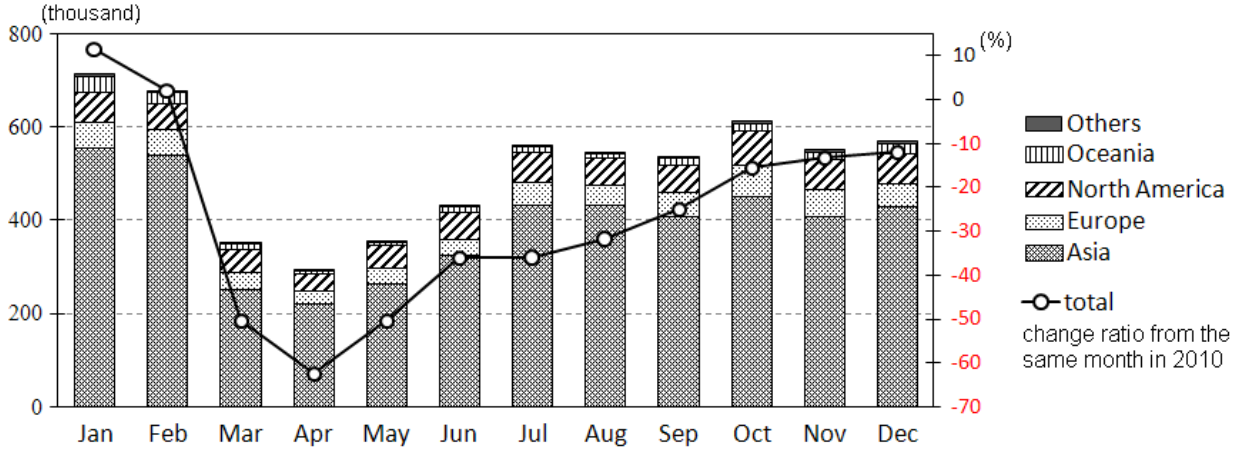


Fig.10 The number of foreign visitors in 2011 by month

source : Japan National Tourist Office

4) Global influence

In addition, damages in the affected area could give the worldwide influences through widely developed supply chains. A interruption of parts' supply from the affected area in Tohoku could cause decrease in automobile production even in the US and EU. Japanese restaurants in China faced shortage of the ingredients for Japanese foods. The East Japan disaster revealed that the affected area was closely connected with other region in Japan and the world economy.★7

8. Activity for rescue and aid

The activity for rescue and help offered officially and voluntarily for the affected area and victims have been conducted or arisen in unprecedentedly extended and enduring scales. Self-defense Forces mobilized totally 107,000 members into the affected area. ★8 Social welfare council set up "Volunteer Center" in every municipality in the affected area, and much of people gathered from all over the country to help victims and evacuee. Total number of VC reached 77 municipalities of six prefectures, among which 66 municipalities belonged to severely damaged three prefectures, that is Iwate, Miyagi, and Fukushima (as of November, 2011). Number of persons participated in voluntary activities of the VCs reached 809,900 (as of October 23, 2011) in those three prefectures.★9

Helps offered from other countries were also extensive. The US Armed Forces in Japan deployed 24,500 soldiers to severely damaged places. Prime minister Kan announced with deep gratitude that 130 countries, 30 international organizations and 670 NGO offered various sorts of aids on March 22, 2011.★10

Almost countless support sites were created on www by the known and unknown user, including various GIS mapping technologies. Total donation to Japan Red Cross and the national government reached 314 billion yen (as of 6, March, 2012).★11

The word of "kizuna 絆" meaning "tie" or "bond" was selected one the most popular words in 2011. Various voluntary activities for helps are continuing even a year after the disaster.

9. Concluding remarks

As known commonly, Japan is a country located in one of the most active tectonic zones in the world, and every geologist and earth scientist in Japan believed that prediction technology for earthquake should be the most excellent in the world. But the March 11 phenomena resulted in the most severe disasters Japan had ever experienced, which surpassed any scales of the predicted earthquake and tsunami and any prevention measures in most of affected regions.

In spite of many helps and political measures to recover the affected region, situation there seems to change little even now. It should be owing to the delay of political decision and legislation for recovery project, as well as unexpected intensity of destruction and areal extent of the affected region. The final value of damage will increase because of secondary damages appearing with time. If we add the nuclear accident related damages, total loss originated from the East Japan Earthquake and Tsunami might increase to nearly infinite number.

A series of the experiences described above has definitely given the significant impacts on Japan both locally and nationally. Rebuilding the devastated region will not easy task to take long time, while the number of evacuee who give up returning to each home place is increasing with elapsed time. According to the inter-prefectural migration report by the Statistical Bureau of Japan, emigrated population in 2011 largely surpassed the same data of 2010 in the Pacific coast prefectures of eastern Honshu (Fig.11).

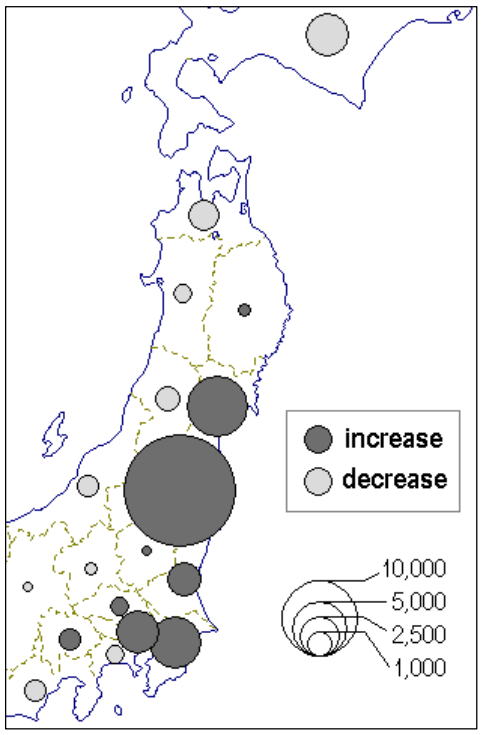


Fig.11 Change of emigrated population in comparison with the same period of the previous year (March to November, 2011)

Japanese people has faced a tuff challenge and in the author's view such situation will continue at least

during the first half of 2010's. Every geographer in Japan is asked to play a role in the road to recovery, utilizing each specialty.

References

★1：http://www.usgs.gov/newsroom/article.asp?ID=2727&from=rss_home

★2：http://www.seisvol.kishou.go.jp/eq/gaikyo/monthly201103/20110311_tohoku_2.pdf

★3：Municipalities in 30km radius from Fukushima Daiichi Nuclear Power Station are left blank owing to delay of retrieval and confirmation of bodies. The figure was made by the author using the data collected and arranged by Yuzuru Isoda (Tohoku University) from following sources:

・Iwate Prefecture (http://www.pref.iwate.jp/~hp0802/oshirase/kouhou/saigaijyohou/20110311.html)

・Miyagi Prefecture (http://www.pref.miyagi.jp/)

・Fukushima Prefectural Police (http://www.police.pref.fukushima.jp/shinsai/index.html)

★4：http://www.kantei.go.jp/saigai/pdf/20110421110001shiji.pdf,
http://www.meti.go.jp/press/2011/06/20110616007/20110616007-2.pdf,
http://www.gsi.go.jp/common/000060521.pdf

★5：Areal designation is supposed to be rearranged to "hard to return area", "habitation controlled area", and "evacuation directive canceled area" depending on yearly accumulative dose after April, 2012.

★6：http://www.jnto.go.jp/jpn/tourism_data/visitor_data.html,
http://www.bugin-eri.co.jp/doc/r111031.pdf（東日本大震災後の東北３県観光事情レポート），
http://www.sangiin.go.jp/japanese/annai/chousa/rippou_chousa/backnumber/20110601.html（廣瀬亮太「日本大震災による被害状況及び復旧・復興に向けた課題 国土交通分野を中心に」，立法と調査，317）

★7：http://www5.cao.go.jp/j-j/wp/wp-je11/h05_hz00.html（平成 23 年度年次経済財政報告）

★8：http://www.sangiin.go.jp/japanese/annai/chousa/rippou_chousa/backnumber/20110601.html（笹本浩「東日本大震災に対する自衛隊等の活動」，立法と調査，317）

★9：http://www.shakyo.or.jp/saigai/torikumi_01.html（全国社会福祉協議会）

★10：http://www.mofa.go.jp/mofaj/saigai/pdfs/bussisien.pdf（諸外国等からの物資支援・寄付金一覧）
http://www.kantei.go.jp/jp/kan/statement/201103/22message.html（諸外国からの支援に対する総理メッセージ）
http://www.mofa.go.jp/mofaj/saigai/pdfs/operation_tomodachi.pdf（東日本大震災に係る米軍による支援トモダチ作戦）

★11：http://www.cao.go.jp/gienkin/pdf/houkoku_20120312.pdf（内閣府義援金受付・送金状況）