Prof. Hrabrin Bachev, PhD, Prof. Fusao Ito, PhD

SOCIO-ECONOMIC IMPACTS OF THE MARCH 2011 EARTHQUAKE, TSUNAMI AND NUCLEAR ACCIDENT ON AGRI-FOOD CHAINS IN JAPAN[1]

Impacts of the March 2011 earthquake, tsunami and Fukushima nuclear accident in Japan on country's agriculture (farms and agrarian resources) and food sector are assessed. The extent of radioactive contamination of agri-food products is presented. Effects on markets, consumers and international trade are evaluated. Responses of different agents are summed up, progress and challenges in post-disaster recovery and reconstruction assessed, and lessons from the Japanese experiences withdrawn.

JEL: Q10; R23; I18; D23

On March 11, 2011 the strongest recorded earthquake in North-East Japan occurred which caused a powerful tsunami and a nuclear accident in one of the world's largest nuclear plants - Fukushima 1. It was the first disaster in history that included an earthquake, a tsunami, and a nuclear power plant accident. The 2011 disasters have had immense impacts on human life, health and property, social infrastructure and economy, natural and institutional environment, etc. in North-eastern Japan and beyond.

There are numerous publications on diverse impacts of the 2011 disasters including on the Japanese agriculture and food sector (see Tsuboi, 2015; Bachev and Ito, 2015; Belyakov, 2015; JA-ZENCHU, 2011; MAFF, 2014; Koyama, 2013; Todo et al., 2015; Pushpalal et al., 2013; MHLW, 2013, 2014; Nakanishi and Tanoi, 2013; Ujiie, 2012; Watanabe, 2011; Watanabe, 2013). Nevertheless, due to the scale of the disasters and affected agents, effects' multiplicities, spillovers, and long time horizon, the lack of "full" information and models of analysis, on-going crisis at the nuclear plant, etc. the overall impacts of 2011 disasters on Japanese agri-food chains is far from being completely evaluated.

A wide range of data are used from governmental, farmers, industry and international organizations, and the operator of the Fukushima nuclear power station (TEPCO), information from publications in media, research and experts reports, detailed interviews with leading experts and representatives of the prefectural governments, farmers, food industries and non-governmental organizations, and affected farmers, business and consumers.

Description of the events and effects

On March 11, 2011 a mega thrust with a magnitude of 9,0 Mw occurred off the Pacific coast of Japan. It was the most powerful earthquake ever recorded in or around Japan, and the fourth most powerful earthquake in the world since 1900

[1] This research is financialy supported by the Japan Foundation.

(JMA, 2011). The earthquake triggered powerful tsunamis that spread over the wide area from Hokkaido Island on the North of the country to Okinawa Island – more than 2000 km to the south. Extensive coastal area surpassing 400 km was hit by tsunami higher than 10 m that submerged plane areas more than 5 km inland and a total area of approximately 561 km^2 or 4,53% of the total territories of the six Northeastern prefectures of Honshu island (GIAJ, 2011). Most affected was the Miyagi prefecture where 16,3% of the territory was flooded by seawater.

The earthquake and the tsunami caused a nuclear accident in Fukushima Daiichi Nuclear Power Plant, Okuma and Futaba, Fukushima prefecture. The 14 meter high tsunami overwhelmed the seawalls and damaged cooling systems and control rooms. Level 7 meltdowns occurred, leading to releases of huge radioactivity into the environment (NISA, 2011). Until May 2012 the cumulative radiation releases amounts 538,1 PBq of iodine-131, caesium-134 and caesium-137, out of which 520 PBq was released into the atmosphere between 12–31 March 2011 and 18.1 PBq into the ocean from 26 March – 30 September 2011 (TEPCO, 2011-2014). Since then there have been continued spills of contaminated water at the plant grounds and into the sea.

Radioactive contamination from the nuclear plant has spread in the region and beyond though air, rains, dust, water circulations, wildlife, garbage disposals, transportation, and affected soils, waters, plants, animals, infrastructure, and population. High levels of radiation were detected in large areas surrounding the nuclear plant and beyond. Numerous "hot spots" have been discovered in areas far beyond the adjacent region. The highest radioactive contamination has been within 20-30 km from the nuclear plant where the authorities have been implementing a 20 km (800 sq km) exclusion zone and other restricted areas.

Long-lived radioactive cesium have contaminated 30,000 sq km of the land surface of Japan while some 11 700 sq km is found to have radiation levels that exceeded allowable exposure rate of 1 mSV per year (MEXT, 2011). In Fukushima prefecture the radiation levels vary according to location, it has been decreasing but it still higher than the levels before the disaster. In other prefectures the environmental radioactivity levels have been stable or decreased but mostly they are still higher than the period before the accident.

The earthquake and the resulting tsunami killed almost 15,900 people (more than 2500 still missing), injured more than 6100 and destroyed the lives of thousands more (NPA, 2016). The biggest number of victims is from Miyagi, Iwate and Fukushima prefectures where whole communities were wiped out. Official figure for disaster related deaths[2] has been growing reaching 3076 in 10 prefectures by March 2014 (NHK, 2014). Many farmers from the affected areas and beyond who saw their businesses and livelihood destructed also suffered stress and anxiety, and some took their lives. UN report pointed out that no deaths or serious illnesses have

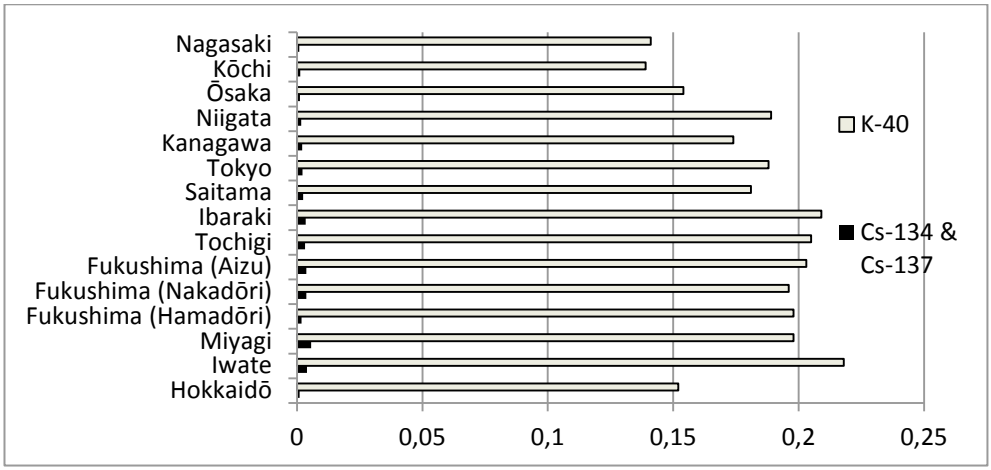
[2] People, who died as a result of having to change their environment and lifestyle, and live as evacuees away from home, family, business and community for a long time period.

been reported from the radiation exposure from the nuclear accident (NHK, 2014). Experts concluded that no discernible increased incidence of radiation-related health effects (cancer) were expected among exposed members of the public or their descendants.

People living and working in different locations of affected regions have been exposed to diverse levels of radiation. Surveys in most affected regions indicate that the annual radiation intakes from foods have been below 1 mSv/year and decreasing over time (Figure 1). In Fukushima prefecture the effective dose from radioactive cesium in foods has been decreasing constantly and it is less than 1% of the maximum allowed level. According to experts the radiation uptake in such ranges is not harmful for human health (MHLW, 2014). Many experts believe that the health effects of the radiation release have been "primarily psychological rather than physical". Many consumers and producers "lose peace of mind" having food with (lower than official safety limit but nevertheless) radiation contamination.

Figure 1

Annual dietary intake of radionuclides for September-October 2012 in Japan (mSv/year)



Source. Ministry of Health, Labor and Welfare.

The earthquake, tsunami and the nuclear accident caused a large evacuation involving some 470 000 (on the third day after the earthquake) and over 320 000 displaced persons on a longer-term basis (RA, 2016). The greatest number of evacuees were from Miyagi, Fukushima and Iwate prefectures where they accounted for 8,37%, 6,3% and 4,39% of the entire population. There are still around 200,000 evacuated people including 70,000 living in temporary housing and other makeshift facilities nationwide (RA, 2016).

Major reasons for the slow progress of reconstruction and returning back of the evacuees have been: a slow pace of decontamination of lands, existing hotspots and restricted mobility in evacuated areas, difficulties of land acquisition for building cites, series difficulties in safe disposal of contaminated soil and debris, population fears regarding radiation hazards, lack of job opportunities, unrestored major services and infrastructure, problems for attracting bids from contractors, spikes in construction material prices and manpower shortages, absence of communities consensus for certain projects, uncertainty for future developments, etc.

Figure 1 shows that 1 196 543 buildings in 20 prefectures have been damaged from the earthquake and tsunami, out of which 10,18% totally collapsed, 22,24% half destroyed, and the rest partially damaged, flooded or burned down (NPA, 2016). In addition, there were damaged roads, bridges, dikes, railways and landslides in 14 prefectures.

The triple disaster has cased destruction of many businesses, which incurred big direct and indirect losses in certain sectors (manufacturing, energy, transport, agri-food etc.) and supply chains in Japan and worldwide (Fujita et al., 2012; GJ, 2012; OECD, 2013; UFJ, 2011). Enormous amount of rubble and debris have been created by the earthquake and tsunami, which affected 239 municipalities of 13 prefectures as total amount of debris is estimated to be about 20 million tons and deposits around 10 million tons (RA, 2016). The nuclear accident has contaminated huge areas of lands and waters, property infrastructure, and debris in Fukushima and neighboring prefectures. Heavily contaminated areas are located in 101 municipalities of 8 prefectures.

Official estimate for the direct economic losses from the March 2011 disaster was about 16,9 trillion yen ($199 billion USD) or 4% of the Gross Domestic Product of Japan (GJ, 2011). The greatest share of damages (61,5%) was for “Buildings, etc. (Housing, offices, plants, machinery, etc.)”, followed by “Others (including agriculture, forestry and fisheries)” (17,7%), “Social infrastructure (river, road, harbors, drainage, and airport, etc.)” (13%) and “Lifeline utilities (water service, gas, electricity, and communication and broadcasting facilities” (7,7%). Anticipated damage in the sector “Agriculture” accounted for 11,24% of the total amount. The World Bank estimated that the economic cost reach up to US$235 billion, making it the costliest natural disaster in world history (World Bank, 2011).

There has been a huge government budget for recovery, reconstructions, compensations and development.[3] Subsequently, there has been a sizeable or complete recovery of damaged infrastructure in the months after the disaster (RA, 2014). There has been an unprecedential speed in the infrastructure recovery in different parts of affected regions as well as of individual sectors of economy and social life (NIRA, 2013). The process of reconstructions has been associated with a

[3] Government approved two supplementary budgets of 6.14 trillion yens for relief and recovery, and a ten-year reconstruction program (for Fukushima, Miyagi and Iwate prefectures) of 25 trillion yens for the period 2011-2015 (RA, 2014).

number of challenges such as: failure for timely evacuation from certain areas, slow response of authorities, lack of sufficient public information at the first stages of disasters, mistrust to public and private institutions, multiple displacements of many evacuees, divided communities and families, bad communication between different organizations, lack of financial resources, insufficient manpower and building materials, ineffective use of public funds, emotional conflicts between evacuees, insufficient and unequal compensation, substandard labor conditions for decontamination workers, increased number of criminal cases, numerous lawsuits against TEPCO and authorities, increasing costs and difficulties associated with decontamination and nuclear plant decommissioning, problems in finding temporary and permanent cites for storing radioactive waste, shortages of electric power, increasing energy supply costs, revisions in national energy, disaster prevention etc. policies, etc.

Affected farms and agricultural resources

There have been many destructed agricultural communities, farms, and agricultural lands and properties from the disasters. The total number of damaged Agricultural Management Entities (AME) of different type (private farms, corporate entities, cooperatives, local public bodies, etc.) reached 37 700 or around 16% of the affected eight prefectures (Table 1). Tsunami affected adversely almost 5% of all farms of the six coastal prefectures. Tsunami damaged AME account for about 27% of all damaged by the disasters entities.

Table 1

Number of damaged AME by 2011 earthquake (March 11, 2012)

Prefectures	Total number of AME	Damaged agricultural entities		Entities damaged by tsunami	
		Number	Share, %	Number	Share, %
Aomori	3733	180	4,8	170	4,6
Iwate	35 321	7700	21,8	480	1,4
Miyagi	47 574	7290	15,3	6060	12,7
Fukushima	50 945	17 200	33,8	2850	5,6
Ibaraki	56 537	1430	2,5	180	0,3
Tochigi	25 010	1330	5,3	-	-
Chiba	17 224	1220	7,1	430	2,5
Nigata	5311	1190	22,4	-	-
Nagano	312	210	67,3	-	-
Total	24 1967	37 700	15,6	10 200	4,2

Source. Ministry of Agriculture, Forestry and Fisheries.

Reported area of agricultural land damaged by the disasters is around 24 500 ha (see Table 2). More than 85% of the washed away or flooded by the tsunami farmlands were paddy fields.

Table 2

Area of damaged agricultural land by the 2011 earthquake
(March 11, 2012)

Prefectures	Damaged agricultural land		Tsunami damaged agricultural land		Share of completely restored agricultural land (%)	Share of restored tsunami damaged land (%)
	Area (ha)	% in total cultivated land	Area (ha)	% in damaged land		
Aomori	107	0,1	77	72	94,4	92,2
Iwate	1209	0,8	725	60	22,2	3,9
Miyagi	14 558	10,7	14 341	98,5	33,3	32,5
Fukushima	5927	3,9	5462	92,1	9,3	4,1
Ibaraki	1063	0,6	208	19,6	90,1	97,1
Chiba	1162	0,9	663	57,1	100,0	100
Total coastal	24 026	2,7	21 476	89,4	32,9	27,3
Yamagata	1	0,0	-	0	100,0	-
Tochigi	198	0,1	-	0	98,0	-
Gunma	1	0,0	-	0	100,0	-
Saitama	39	0,0	-	0	100,0	-
Niigata	117	0,1	-	0	73,5	-
Nagano	95	0,1	-	0	69,5	-
Total inland	451	0,1	-	0	85,8	-
Total	24 477	1,6	21 476	87,7	33,8	27,3

Source. Ministry of Agriculture, Forestry and Fisheries.

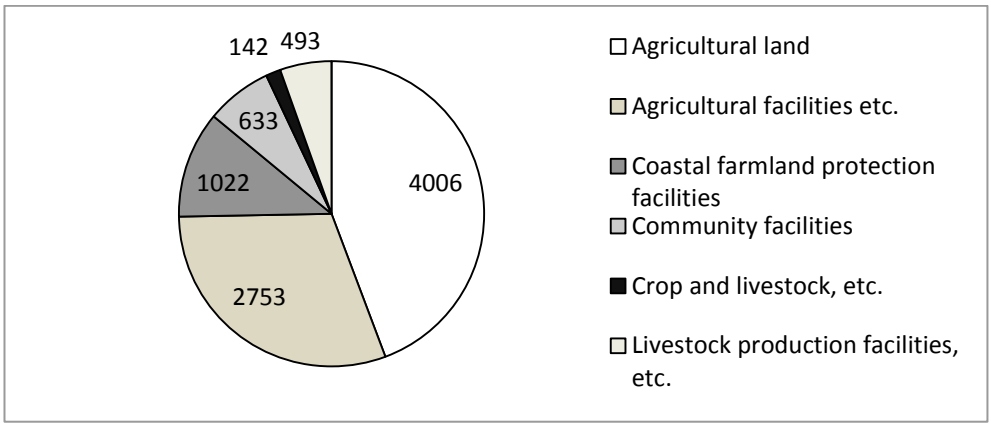
There has been radioactive contamination of farmlands from the nuclear accident's fallout. Survey in the most affected regions shows that contamination with cesium of paddy fields ranges from 67 up to 41 400 Bq/kg and for arable lands, meadows and permanent crops from 16 to 56 600 Bq/kg. Most heavily contaminated farmlands are in Fukushima prefecture 3,6% of all samples (including 4% of the paddy fields) are above 5000 Bq/kg.

A massive destruction of livestock, fruit trees and crops followed in the regions affected by the disasters. The total crop and livestock damages from the earthquake are estimated to be worth 14,2 billion yen (MAFF, 2012). Damages on farms have been particularly big in areas around the Fukushima nuclear plant, where most agricultural land, livestock and crops were heavily contaminated and destructed (Koyama, 2013; Watanabe, 2011, 2013). In the most seriously affected evacuation areas farming activity has been suspended or significantly reduced, and the majority of livestock and crops destroyed.

The official estimate for the inflicted damage on agriculture by the 2011 earthquake is 904,9 billion yen (Figure 2). The biggest share of the damages is for agricultural land and agricultural facilities, followed by the coastal farmland protection facilities, community facilities, agricultural livestock etc., and agricultural crop and livestock etc. The greatest amount of damage has incurred in Miyagi prefecture representing 56,5% of the total worth.

Figure 2

Damages to agriculture from 2011 earthquake as of July 5, 2012
(100 million yen)

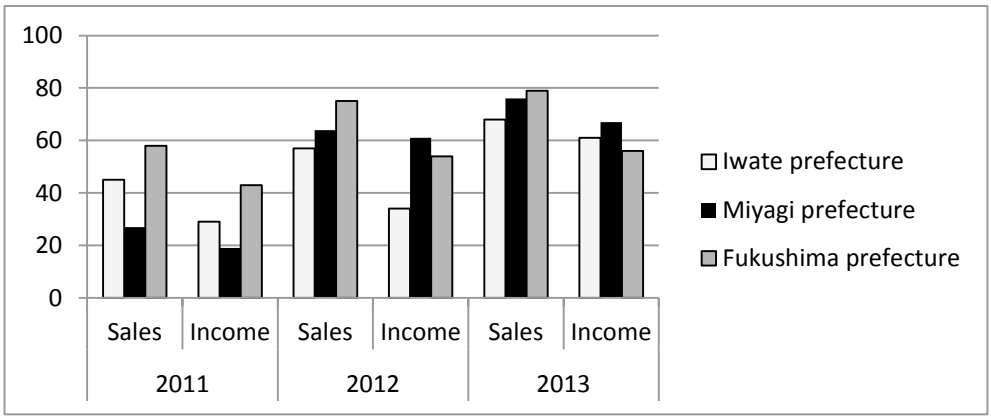


Source. Ministry of Agriculture, Forestry and Fisheries.

A survey on the economic situation of the agricultural management entities in the tsunami damaged areas established that in 2011 the sales revenues from agricultural products dropped by 68% comparing to 2010 and the agricultural income by 77% (Figure 3). Severe blows on sales and income were registered by producers in the three dominant type of farming in the region (Figure 4).

Figure 3

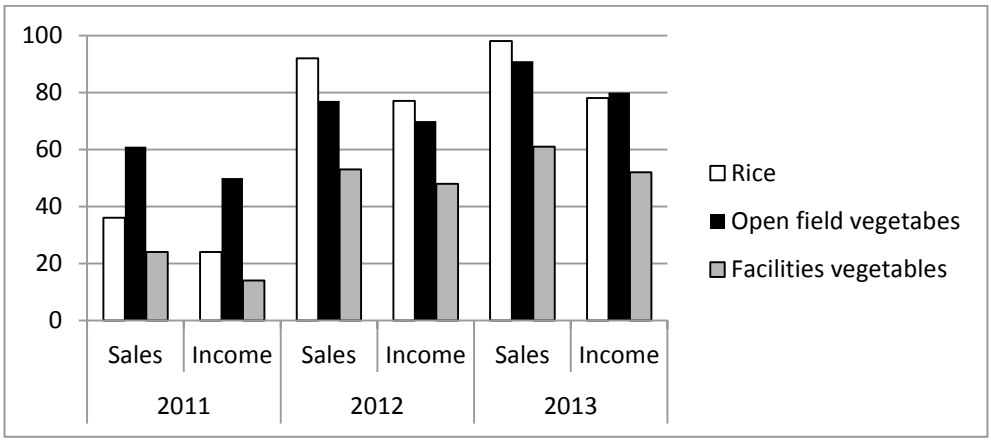
Evolution of agricultural sale and income of agricultural management entities in tsunami-damaged areas (2010=100)



Source. Ministry of Agriculture, Forestry and Fisheries, 2013.

Figure 4

Evolution of agricultural sales and income of agricultural management entities with different specialization in tsunami-damaged areas (2010=100)



Source. Ministry of Agriculture, Forestry and Fisheries.

There have been some improvements of sales and incomes in all areas but in 2013 they were still far below the 2010 level The slower growth of income compared to sales (in Iwate and Fukushima prefecture) was due to higher costs associated with the post-disaster cleaning and rebuilding. There has also been a considerable progress in recovery of sales and income of rice and vegetable farms but in 2012 their levels were still much lower than in 2010. The slower pace of post-disaster recovery in the facility grown vegetables was caused by the prolonged farmland restoration and the high (facility) rebuilding costs after the land restoration is complete and operation resumed (MAFF, 2014).

The total product damages from the accident accounts for 2,568 billion yen in Fukushima prefecture, out of which 41,9% are in the evacuated and restricted areas (Table 3).

Table 3

Agricultural product damages in areas affected by nuclear disaster in 2012

	Vegetables	Livestock	Fruit	Rice	Evacuated/restricted area total	Fukushima prefecture
Evacuated/restricted area share (%)	42,4	68,0	48,9	35,9	-	100
Evacuated/restricted area (100 million yen)	225	346	135	371	1077	2568
Evacuated/restricted area ratio (%)	8,8	13,5	5,2	14,4	41,9	100

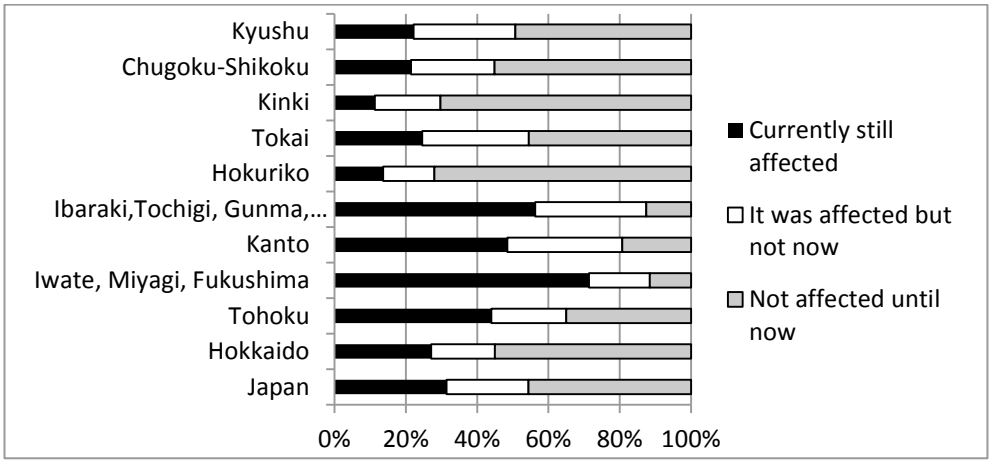
Source. Tohoku Department of Agricultural Administration, MAFF Statistics.

These figures cover damage of products that cannot be sold, because of the restrictions on planning and distribution, and the loss of the value caused by rumors. Nevertheless, the above assessment does not include important "stock damage" (material funds, damage to production infrastructure, contamination of agricultural land, facilities for evacuation, and usage restrictions on machinery) as well as the loss of "society-related capital" (diverse tangible and intangible investments for creating production areas, brands, human resources, network structure, community, and cultural capital, ability to utilize resources and funds for many years). The later losses are quite difficult to measure and "compensate" (Koyama, 2013).

There has been a significant short and longer-term negative impact of the triple disaster on farm management entities in the most affected prefectures and beyond. Disaster affected negatively almost 55% of Japanese farms (Figure 5). A 2012 survey has found out that the most severely affected have been the farmers in Tohoku and Kanto regions. In the worst hit prefectures more than 88 - 89% of all farms "are still affected" or "were affected in the past" from the earthquake, tsunami and nuclear accident.

Figure 5

Adverse effects of Great East Japan Earthquake on farm management in different regions of Japan (March 2012)



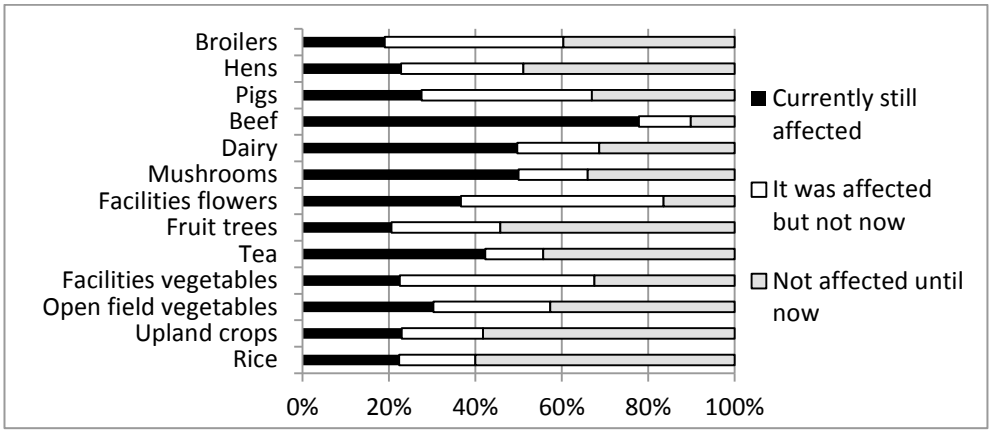
Source. Japan Finance Corporation.

One year of the disaster 31,4% of the surveyed farms in the country reported adverse effect on their management by the disasters. More than 71% of the farmers in Iwate, Miyagi, and Fukushima prefectures, and more than 56% of those in Ibaraki, Tochigi, Gunma, and Chiba prefectures continued to feel the adverse effects.

Among different sectors of agriculture most of the farms have been affected by the disasters in beef and facility flowers production (see Figure 6).

Figure 6

Adverse effects of Great East Japan Earthquake on farm management in different subsectors of Japanese agriculture (March 2012)



Source. Japan Finance Corporation.

There are huge differences in the most affected sectors in different regions of the country. In Iwate, Miyagi, and Fukushima prefectures a great majority of farms in beef, dairy, mushroom, facility vegetables, fruit trees and rice cultivation are still adversely affected by the earthquake, tsunami and nuclear accident.

The major reasons for the negative impacts of the triple disasters have been "decline in sell prices" and "harmful rumors" while the damaged inputs supply and production affected less farms (Table 4).

Table 4

Reasons for those who are currently adversely affected in different regions (August, 2011; January 2012)*

	Damage to production		Damage input supply		Damage to distribution		Decline in sell prices		Harmful rumors	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Japan	24,5	23,2	41	27,1	44,4	33	65,8	74,4	52,8	60,5
Hokkaido	12,6	14,1	55,9	39,7	34,4	31,3	63,5	79,8	44,1	46,4
Tohoku	46,3	38,2	51,5	25,2	60,8	41	55,2	65,8	58,3	72
Kanto	34,1	26,1	28,8	17,6	45,2	27,8	69,6	72,8	72,9	76,1
Hokuriko	12,4	14,8	47,6	29,6	40	24,1	44,8	63	45,7	55,6
Tokai	7,6	7,3	30,5	18,2	41,9	34,5	86,7	87,3	35,2	43,6
Kinki	5,4	11,4	25	28,6	29,3	25,7	73,9	77,1	44,6	28,6
Chugoku-Shikoku	6,3	9,7	31,7	23,9	33,7	29,2	72,6	80,5	38	50,4
Kyushu	8,6	9,1	27,9	29,9	40,5	32,5	77,5	86,8	37,5	36

* Multiple answers.

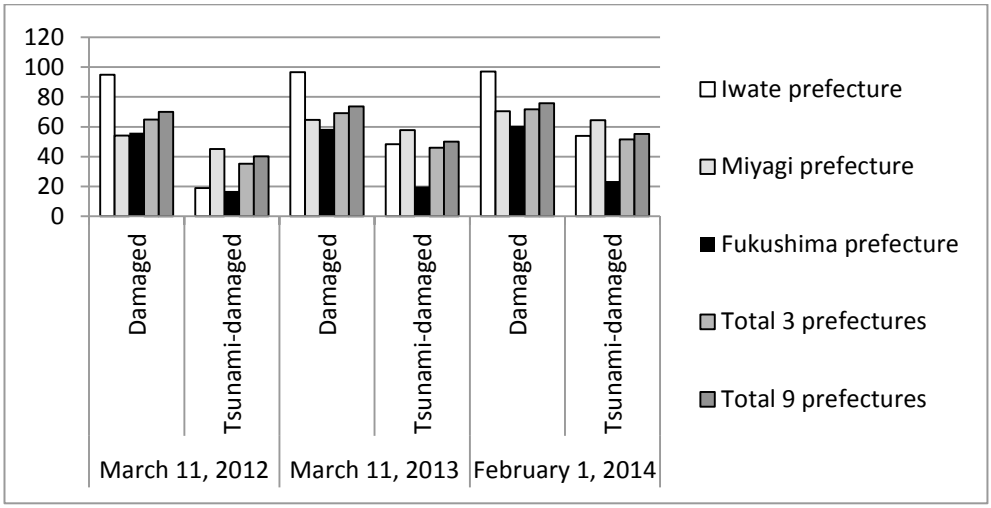
Source. Japan Finance Corporation.

For farmers still affected by the disasters the importance of the first two factors increased considerably in 2012 comparing to the disaster year. “Damaged production” has been a major factor for the most broilers producers, “damaged input supply” for the majority of pigs, upland crops, and open field vegetables producers, while “declined sell prices” and “harmful rumors” impacted farmers in all sectors. In 2012 the impact reduced sell prices further increased for most subsectors, while of the harmful rumors for all producers.

MAFF worked out a “Strategy for the Revitalization of the Agriculture, Forestry, and Fisheries” (2011) aiming to rapid restoration and resuming of farming in disaster affected regions. A good progress in removal of debris, restoration of damaged agricultural lands, and resumption of farming has been achieved with concerted efforts of government agencies, prefectural and local authorities, agricultural cooperatives, farmers, private companies, volunteers etc. One year after the disasters around a third of damaged agricultural land was completely restored, including 27% of the tsunami damaged farmlands. During the same period about 90% of tsunami-afflicted farmland was cleaned of rubble, a large part of agricultural infrastructure reconstructed (MAFF, 2012). Consequently, 70% of all damaged farms in 9 prefectures and 40,2% of tsunami damaged farms in 6 prefectures and 40% of resumed farming (Figure 7).

Figure 7

Share of agricultural management entities, which resumed farming (%)



Source. Ministry of Agriculture, Forestry and Fisheries.

By March 2013 restoration and salt removal on 38% of the tsunami-damaged farmland was completed and they were available for farming (with restoration on another 63% ongoing) (MAFF, 2013). That was close to the target in the 3 years

plan for complete restoration of tsunami-damaged farming. Consequently, a half of the affected by the tsunami farms resumed agricultural production or preparations for it (MAFF, 2013).

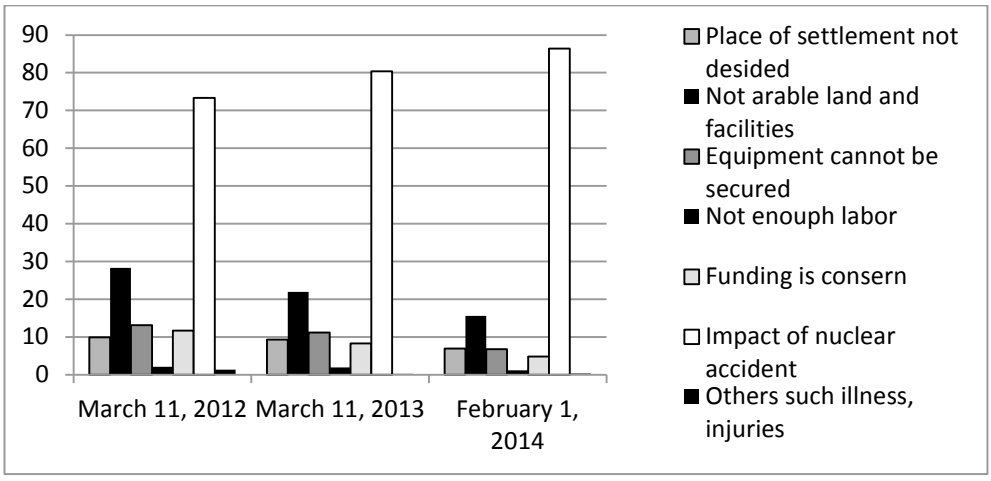
Around 63% of tsunami damaged agricultural land has been made again available for farming (RA, 2015), and more than 55% of the affected farms resumed operation. Agricultural land in Miyagi prefecture was planned to be fully recovered by 2015 but the officials announced that will be delayed by a few years.

In Fukushima prefectures restoration of operations in damaged farms has been progressing slowly. Until June 2014 merely 29,9% of the tsunami-damaged farmland has been restored and become available for farming, 82,3% of damaged agricultural facilities have been restored, and 60,9% of agricultural management entities resume operations (MAFF, 2014). Similarly, merely 69,3% of the planed agricultural lands (paddy, upland, orchards and pastures) from the Municipality decontamination area have been actually decontaminated (RA, 2014). Some parts of heavily contaminated areas remain almost untouched and probably require a long time before farming can be resumed.

Major reasons for "not resuming farming" in the three most affected prefectures have been the impact of nuclear accident, unavailable arable land, facilities and equipment, undecided place of settlement, and funding problems (Figure 8). Importance of most of these factors has been decreasing due to continuing reconstruction, returning of evacuees, restoration of farmlands and public support measures. Significance of the nuclear crisis as a reason deterring effective resumption of operations by majority of farms has been increasing.

Figure 8

Reasons for not resuming farming in Iwate, Miyagi and Fukushima prefectures, multiple answers (% of farms)

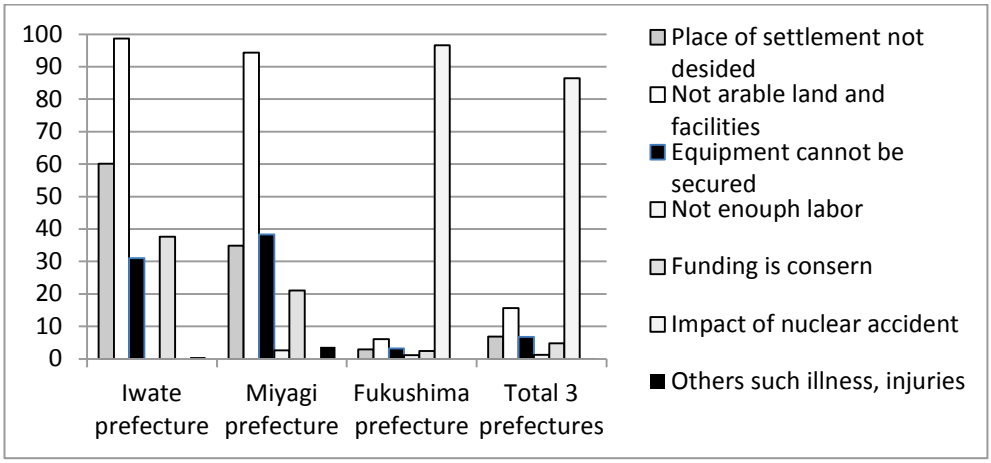


Source. Ministry of Agriculture, Forestry and Fisheries, 2014.

Most critical factors for "not resuming farming" for majority of farms in Iwate and Miyagi prefectures have been the unavailable arable land and facilities (Figure 9). Other important factors for a significant number of farms in these prefectures are that farmers have still not decided themselves on the place of settlement, funding of farming activities is an issue, and equipment can't be secured. The most important obstacle to restart operations for the most Fukushima farmers has been the "impact of nuclear accident".

Figure 9

Share of farms with diverse reasons for not resuming farming, multiple answers (%)



Source. Ministry of Agriculture, Forestry and Fisheries, 2014.

The enormous public funding as well as the novel business possibilities (and restrictions) have created new opportunities for revitalization and expansion of farming in the most affected regions and beyond trough technological and organizational modernization. There have been huge incentives for investment in soil decontamination, emergency aid, agri-food safety, production recovery and modernization, product and technologies innovations and diversification, agri-food marketing, restructuring of business and infrastructure, other public and private research and development projects. All of them have been opening up more entrepreneurial, employment and income opportunities for agricultural and general population, and diverse form of business and non-for profit ventures (Bachev and Ito, 2015).

MAFF launched the National Specific Program for farmlands and farming facilities which is implemented to enlarge partitions for farmlands. For instance, the East Sendai District Farmland Consolidation Project covers 1979 ha out of the 2244 ha as the ratio of consent by the landlords for consolidation is 94,6% (CS, 2014). There are many applications to lease in abandoned farmland and to start

large-scale corporate farming. That will consolidate and enlarge farm size, introduce large-scale machineries and innovations, explore economies of scale and scope, increase investment and efficiency, diversify and improve competitiveness of farming enterprises.

The disaster has induced further expansion of a “no-soil” factories in Japan which has been perceived as an efficient way to overcome some of the major challenges associated with the post-disaster recovery in the affected regions – salinized or radioactive soils, destructed farms and equipment, lack of employment and income opportunities, aging farm population, insufficient integration in supply chain, etc. Another prospective technology applied in the disaster-hit area is “solar sharing” - a process in which farmers generate solar power on the same land where they grow crops.

Other innovations as production of clean bio-energy have also been experimented. Increasing applications of ICT in agriculture have also been reported leading to precision technologies, higher farming productivity, efficient use of resources, enhanced food safety, and improved relations with counterparts and consumers. The demand for proper measurements have induced numerous smart innovations as systems that can quickly analyze the density of strontium in soil and agri-food products.

In the years after the nuclear accident an increase in interests in renewable energy introduction has been reported, including in agriculture. That is motivated by the new opportunities of development (including Government support) and growing costs of energy supply. As much as 11,6% of AMU in Japan already use renewable energy, 10,2% of them are planning to do so, while 57,3% of all report interests in introduction of renewable energy (JFC, 2014). The highest rate of usage or planning of introduction of renewable energy is in Broilers, Dairy and Tea productions, while the lowest is in Rice cultivation. The “Solar” energy is reported by the largest number of agricultural producers who use, plan to or are interested in introduction of renewable energy in all regions. The Tea and Upland crop producers are particularly strongly using or interested in that energy source. Almost every forth of the farms using, planning or interested in introduction of renewable also report Wind energy as application or interest to that energy source is the highest among Rice producers. The third most important source of energy in agriculture is Biomass as usage and interest to biomass is the highest among Pig, Broilers, and Dairy farms.

Impact on food industries

After March 2011 the food industry in the disaster regions and throughout the country was seriously affected by the production drops, business suspensions, distribution ruptures, etc. due to damaged plants, rolling blackouts, packaging material production shortages, gasoline shortfalls, etc. (MAFF, 2011).

Surveys on food industries dynamics revealed that 71% of the country’s food companies were “affected” by the March disasters, including more than 35% “still affected” at the beginning of 2014. The strongest hit were food-industry companies

in Tohoku's most affected regions (Iwate, Miyagi and Fukushima prefectures) (92,5%) and in Northern (84,6%) and Southern (82,3%) Kanto region. A significant share of food industry has not yet recovered from the disaster by the end of that year in Iwate, Miyagi and Fukushima prefectures and Northern Kanto region.

Similarly, 57,9% of country's food companies have been negatively affected by the Fukushima nuclear disaster as about 35% were still affected in the beginning of 2014. Most severely affected have been the companies in Northern Kanto (83,4%) and in Tohoku's Iwate, Miyagi and Fukushima prefectures (81,9%). In the most impacted Fukushima prefecture 93,8% of all food companies have been adversely affected by the nuclear accident, including 92,6% of them "still affected" in the beginning of 2014 (JFC, 2014).

The most common reasons for the negative impact of the triple disasters are: the reduction in sales volume, the increase in the price of ingredients and materials, and the decrease in the demand and number of costumers. There has also been reported a great variation of the individual factors for the adverse impact of nuclear accident in different regions of the country.

There are differences in the adverse impact in different subsectors of food industry too. According to 2014 survey the earthquake and tsunami have affected negatively the selling prices, procurement of ingredients and raw materials, and demand from trade partners of a large number of food industry companies. Disasters affected severely the Procurement of ingredients and raw materials of the majority of companies in all subsectors. In addition, disasters affected the demand from trade partners of many companies in wholesale trade, and the sales volume, number of consumers, and the price of ingredients and raw materials in restaurant business.

Fukushima nuclear disaster has also affected mostly demand from trade partners, sales volume, and procurement of ingredients and raw materials of many food companies. Most food manufactures and wholesale traders suffered mainly from the decrease in the demand of trade partners, while most the restaurant operators and retailers the procurement from supply of ingredients and raw materials.

Radioactive contamination of agri-food products

A large scale contamination of crops, livestock and agri-food products by radionuclide was due to the direct radiation exposure, the fallouts and distributed by wind and rains radioactive elements, the crop and livestock uptakes from leaves, soils, waters and feeds, the diffusion from affected inputs, buildings and equipment, the dissemination through transportation and wildlife, etc. During the year after the nuclear accident officials tested 137 037 agri-food samples across the country and detected 0,88% exceeding the provisional safety limit in 14 prefectures (MHLW, 2014). Most of the contaminated food samples were in Fukushima prefecture (59,63%), Saitama (10,55%), Ibaraki (7,14%), Tochigi (6,23%) and Miyagi (5,32%). The majority of highly contaminated items in Fukushima prefecture were vegetables, fishery products and meats, in Ibaraki and Chiba vegetables, in Miyagi beef, in Tochigi vegetables and meats, in Saitama and Tokyo tea leafs. More than 3600

fishery products were tested in Fukushima prefecture during the first year after the accident, and 34,7% of them found above 100 Bq/kg (MAFF, 2014). In the rest of the country from almost 5000 inspected fish samples 4,5% were above safety norm.

The mandatory and voluntary restrictions on shipment covered a number of products from designated areas of affected regions. In addition, there was a ban on rice planting on 8000 ha of paddies in evacuation (95%) and other contaminated areas (MAFF, 2012).

In order to meet growing public safety concerns since April 1, 2012 new more stringent official limits on radioactive elements in food items have been enforced in the country. Official, collective, and private food inspections have multiplied in the 17 most vulnerable prefectures and around the country. Official inspections results in the last four years indicate that for all agricultural food products, except mushrooms and wild edible plants, the number of samples with radioactive cesium above safety limits is none or insignificant (Table 5).

Table 5

Results of inspections on radioactivity levels in agricultural products in Japan *

Products	March, 2011 - March 31, 2012			April 1, 2012 - March 31, 2013		April 1, 2013 - March 31, 2014		April 1, 2014 - March 31, 2015	
	Number of samples	Above provisional limit	Above new limit	Number of samples	Number of samples	Above provisional limit	Above new limit	Number of samples	Number of samples
Rice	26 464	39	592	11 mil.	28	10,4 mil.	84	11 mil.	2
Wheat and barley	557	1	27	592	0	1818	0	383	0
Vegetables	12 671	139	385	19 657	0	18 570	5	16 712	0
Fruits	2732	28	210	4243	0	4478	13	3302	0
Pulse	698	0	16	6727	59	4398	25	3459	4
Other plants	498	1	16	1613	0	3094	14	1049	0
Mushrooms and wild edible plants	3856	228	779	7583	194	6588	605	8557	103
Tea/Tea infusion*	2233	192	1,562	446**	0**	867**	13**	206**	0**
Raw milk	1937	1	7	2052	0	2453	0	1846	0
Beef	91 973	157	1096	208 477	0	187 176	6	na	
Pork	538	0	6	693	0	984	1	na	
Chicken	240	0	0	385	0	472	0	na	
Egg	443	0	0	418	0	565	0	na	
Honey	11	0	1	66	0	124	0	na	
Other livestock	23	0	0	118	0	99	1	na	

* For crops in 17 northeastern and eastern prefectures; for livestock products - all prefectures.

Source. Ministry of Agriculture, Forestry and Fisheries.

Test data for marine fishery products radioactive contamination also indicate that the number of cases above safety limit has dropped considerably. In Fukushima prefecture, in the months after the accident, the share of highly-contaminated fish was 57,7% but it was reduced by half after one year up to 1,5-1,7% in the last three quarters. In other prefectures the share of contaminated fish decreased from 4,7% to less than 1%.

Surveys on the levels of radioactive cesium in home-made meals in Fukushima prefecture shows that mostly they are below the maximum admissible limit - out of 100 households surveyed only 4% showed measurements slightly above the limit for radioactive cesium (Fukushima Minpo News, March 7, 2014). Household members were also tested for internal exposure to radioactive materials by a whole-body counter, and all screened persons had counts below the threshold for human radiation exposure.

There are still a number of products from certain areas of 17 prefectures, which are subject to mandatory or voluntary shipment restrains (MAFF, 2016). In Fukushima prefecture restrictions cover a wide range of vegetables, fruits, livestock and fish products grown in heavily contaminated areas. There is also a ban on rice planting on 2100 ha (almost 3 times less than in 2013) and overall production management restrictions on 4200 ha paddies in the evacuation area. In other prefectures mandatory and voluntary shipment restrictions mostly concern mushrooms, wild plants, and fish.

Effects on markets, consumers and international trade

In the days after the disasters there was a destruction of supply of potable water, foods and other necessities in most affected regions (MAFF, 2011). What is more, food shortages spread beyond the worst affected areas as many people were panic buying after the nuclear crisis. Unprecedentially for the post war period situation of food rationing and empty stores shelves was prevailing in the days after the crisis across the disaster areas and big cities. “Normal” food supply to all people affected by the disasters was quickly restored and important infrastructure (production and storage facilities, wholesale markets, transportation network etc.) rebuilt. There have been numerous restrictions on production, salea, shipments and consumption of basic agricultural and food products in the regions affected by the nuclear accident which stopped, delayed or significantly reduced the effective supply of many local agri-food products.

Due to genuine or perceived health risk many Japanese consumers stop buying agricultural, fishery and food products originated from the regions affected by the nuclear accident. Even in cases when it was proven that food is safe some wholesale traders, processors and consumers restrain from buying products from the contaminated areas (see Futahira, 2013; Koyama, 2013; MAFF, 2014; Watanabe, 2011, 2013). Demand for many traditional farm produces from the affected regions (such as rice, fruits, vegetables, mushrooms, milk, butter, beef etc.) significantly declined while prices considerably decreased. Regardless of the good result from the inspection for radioactive contamination of rice the circulation of all rice produced in Fukushima prefecture stopped in 2011-2012, and demand and prices have not been recovered.

Consumers’ attitude toward the agricultural products from the regions affected by the nuclear disaster has changed dramatically (Ujiie, 2012). Almost 38% of the consumers surveyed in 2012 indicate that they do not purchase fresh

foods produced in the affected by accident areas, and only 8,4% say they buy (JFC, 2012). A different survey has found out that a half of the consumers in Tokyo and Osaka would not buy Fukushima and Ibaraki products with "contamination less than the official criteria" and other 30% said they would not buy if products were "not contaminated at all" (Ujiie, 2012). A follow up survey reveals that while consumers still maintain the high risk conscious, the "origin of product" factor playing less important role is their choice.

Even residents and producers of Fukushima prefecture tend to avoid buying local products and this is particularly true for some segment of population (family with children) as well as for certain products (mushrooms and seafood).

Countrywide survey found out that more than a third of surveyed farmers and almost of 38% of food industry personnel indicate that "Sales slackened because consumers tended to refrain from buying food products" (MAFF, 2013). The latter figures are much higher for the regions most affected by the disaster. Moreover, a substantial number of food industry companies point out that they "switched from agriculture, forestry and fisheries products in areas with radioactive contamination fears to those in other areas (in Japan) for our purchasing" and that amounts to more than 57% in Fukushima prefecture.

After the nuclear accident, there was a considerable decline in absolute and relative prices of affected farm products and products from the contaminated regions. Fukushima is Japan's fourth biggest rice-growing prefectures with rice accounting for about 40% of the prefecture's agricultural output. After the nuclear accident the price of Fukushima rice fell in both absolute and relative terms Watanabe, 2011, 2013). In 2012 rice prices in Fukushima prefecture bounced back in absolute terms but continue to stay relatively lower comparing to rice grown elsewhere. The same has been true for vegetables, fruits and livestock products like beef etc.

According to experts both producers and consumers are victims of the "reputation damage" (Koyama, 2013). A survey in 2013 found out that 26,1% of the consumers do not even know that inspections of radioactive contamination are being conducted (CAA, 2014). In order to facilitate communication with consumers to promote and recover Fukushima agricultural products numerous initiatives have been undertaken by farmers, agricultural organizations, NGOs, authorities, business, retailers etc. such as: direct sales by farmers, on spot radiation tests, recovery markets, Farmers' Document and Farmers Café events, government "Eating for support" initiative, joint ventures with shops, promotion complains with participation of top officials, celebrities, journalists, and farmers in big cities, international fairs etc.

Fights against "harmful rumors" that led to plummeting prices and sales of farm products have been a high priority for local and national authorities. In fiscal 2015 Fukushima prefecture spent about 1,7 billion yen ($16,6 million) to fight rumors about radiation - fourfold budget increase over the previous year. The prefecture hired a popular idol group for commercials to promote its agricultural produce in Tokyo area as

the ratio of respondents who said they "do not want to buy" Fukushima produce dropped by about 10 points from 27% after ad viewing.

The central government help revive industries suffering from groundless rumors following the nuclear accident. The new guidelines for helping local businesses are prepared saying that: the government will continue releasing the results of radioactivity tests on agricultural products from Fukushima prefecture; officials will continue to urge foreign countries to ease or abolish import restrictions on farm and fisheries products; they call on member companies of the Japan Business Federation to use farm products from Fukushima prefecture as gifts and offer them at in-house sales events; officials will work to attract tourists, including students on school trips, from inside and outside Japan; and urged the related agencies to lead the way to help give the industries a boost.

Recent data suggest that demands for Fukushima, Ibaraki and Northern Honshu agricultural products have been recovering fast while the farm-gate and wholesale prices in the most affected regions are still lower than in other parts of the country. This is a consequence of a number of factors: reduction of radioactive contaminations, improving consumer confidence on inspection and safety, "forgetting" the contamination issue by some part of population, preferences to lower prices regardless the quality by some segment of consumers, changing marketing strategies of processors and smaller shops (not promoting/labeling any more some farming and processed products as "Fukushima origin"), increasing procurement by restaurants and processors of safe and cheap produces from the region etc. Consequently, despite the negative impact on local producers in affected region some actors in the food chain (restaurants, food stores, intermediaries) have been profiting enormously getting a higher margin.

In 2011 the daily intake per person for some of the food groups most likely affected by the nuclear disaster decreased comparing to the period before the accident – mushrooms by 12,5%, seaweeds by 5,4%, pulses by 6,5%, etc. (MHLW, 2014). That change in the consumption pattern is probably a consequence of the newly emerged consumers risk concern, higher procurement costs or other (unspecified) reasons.

Disasters also affected considerably the international trade with agricultural products. Around 40 countries imposed restrictions on agri-food import from Japan after the nuclear accident, including major importer (China, United States, Indonesia, Malaysia and South Korea). By March 1, 2013 about 10 countries completely lifted radionuclide related restrictions on food products from Japan including Canada, New Zealand, Malaysia, Mexico, Peru, Chile, Columbia, Guinea, Myanmar, Malaysia and Serbia. EU also substantially eased import restrictions from 11 prefectures but kept restrictions for products from Fukushima prefecture.

Due to the foreign countries' import restrictions and the incurred damages, the value of Japan's farm and livestock product exports declined substantially - in April-December 2011 the export plunged by 40,9 billion yen (11%) from the year before (MAFF, 2012). Furthermore, in January-March, 2012 the value of country's export of agricultural products was 89 million yen (12,77%) lower than for the same period

before the disaster. There was a considerable decease in the overall agricultural and fishery products export in 2011. At the same time, there was a significant increase in the import of agricultural, forestry and fishery products as imports of farm products jumped 16%(to 5,58 trillion yen) in 2011. In April-December 2012 a 5,98% growth was registered in the export of agricultural products of the country. A slight augmentation of the annual exports of agricultural and field crops products was reported but the export value was still bellow 2010 level. The overall import of agricultural and crop products decreased but it was still above the pre-disaster levels. Fish products exports continue to enlarge.

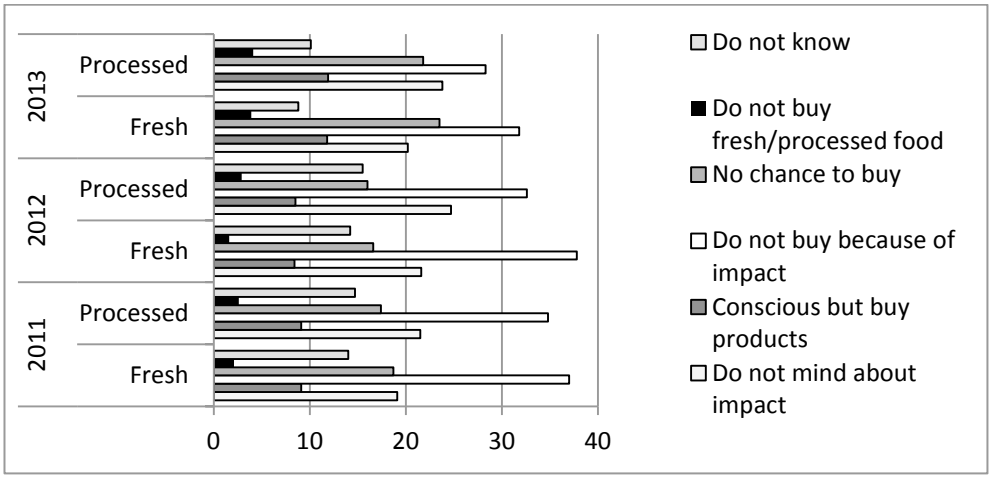
There has been a significant change in the purchase behavior of a great number of consumers after the disasters. The July 2011 survey found out that a good share of consumers decreased the purchased amount of fresh (10,6%) and processed (9,8%) food, ornamental flowers (21,6%), confectionary (15,2%), etc. while there is an increase in purchase of mineral water (17,6%) (JFC, 2013). These changes were more dynamic in the worst affected East Japan than in the other parts of the country.

In the months after the disaster the item most emphasized by the consumers at the time of purchase of fresh food was “production location” and for processed food the “origin of raw materials”. For the majority of consumers there was no change of the place to buy fresh (88,5%) and processed (89,1%) food comparing to the pre-duster period (JFC, 2011).

The consumer attitude to purchase food products from the regions affected by the nuclear disaster has evolved in post disaster years (Figure 10).

Figure 10

Awareness when purchasing fresh and processed food from the region after Fukushima nuclear power plant accident (July 2011, January 2012, January 2013)



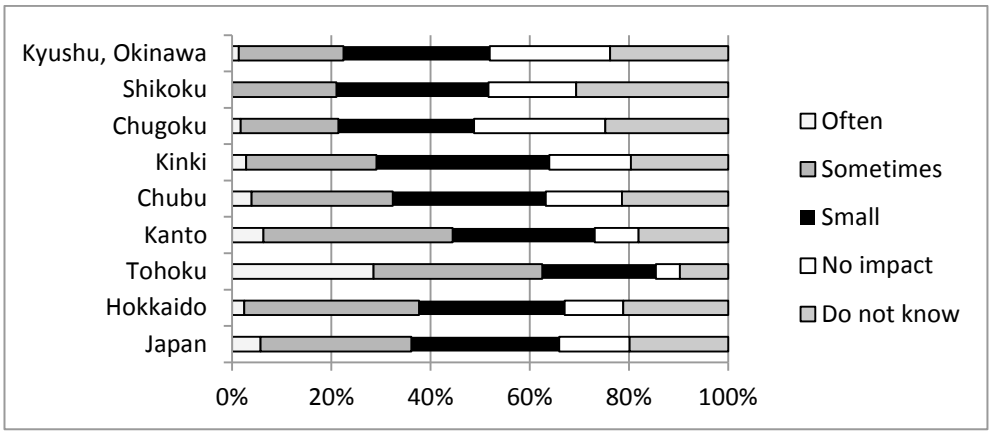
Source. Japan Finance Corporation.

Currently, relatively more and more consumers do not mind the impact of the nuclear disaster when purchasing agri-food produce. Nevertheless, still a significant share of consumers do not buy fresh (31,8%) and processed (28,3%) products from that regions because of the impact of the nuclear disaster.

Recent data indicate that a good portion of Japanese consumers (36,5%) "often" or "sometimes" purchase foodstuffs from areas affected by the 2011 disasters (Figure 11). The latest figure is much higher in Tohoku region then in the other parts of the country.

Figure 11

Purchase of (processed goods and agricultural products) foodstuffs produced in areas affected by the Great East Japan Earthquake (including eating out) (January 2014)



Source. Japan Finance Corporation.

There are gender and age differences in willingness to buy from the affected regions as older generation and women tend to buy more from the affected regions than the younger generation and men (JFC, 2014). For a great proportion of the consumers it is important to select the region of agri-food products and they purchase "rarely" or "not at all" from the affected regions. Diverse promotions about produce safety etc. increase consumer willingness to purchase products from the affected regions (JFC, 2014). For most Japanese consumers who do not want to purchase food stuff from the affected regions even if there is a promotion the main reasons is "worry about safety".

All surveys show that there is increased awareness of the needs to keep foodstuff at home after the 2011 disasters (JFC, 2014). Around 29,5% of consumers report they kept food stockpiles at home event before the disaster, 21,5% are keeping such piles after the disaster (much higher percentage in worst affected regions), while 7.9% kept after the disaster but currently not (much higher in Tohoku).

*

Five years after the 2011 triple disaster in Japan a number of conclusions on the agricultural and food chain impacts could be made. Agriculture, food industry and food consumption have been among the areas worst hit by the disasters. Agri-food sectors of Fukushima, Miyagi and Iwate prefectures have been particularly severely affected in the short and longer term. There are also significant adverse consequences on other regions and entire food chains at a regional, national, and international scale. There is a great variation of the specific and combined impacts of the earthquake, tsunami, and nuclear disaster on different type of farming and business enterprises, particular agents, individual sub-sectors, and specific locations. There have been enormous damages and long-term consequences on farming and rural households, important properties, personal ties, established brands, informal organizations and traditional communities. Many of all these negative effects can hardly be adequately expressed in quantitative (monetary) terms. Disasters have considerably aggravated some already existing problems of the agrarian and rural regions such as: aging and shrinking population, lack of labor and young entrepreneurs, low competitiveness and efficiency, income and services disparities, etc.

Disasters have had positive impacts on the development of sectors in the most affected regions and some sectors in other parts of the country. The post disaster recovery and reconstruction have given opportunities and induced considerable policies and institutional modernization in agri-food and other sectors, food safety information and inspection, technological and product innovation, jobs creation and investment, farmlands consolidation and enhancement, infrastructural amelioration, organizational restructuring, etc.

This study was just a first attempt to specify and assess the overall impact of the March 2011 disasters on Japanese agriculture and food chains. Reasonably the research is incomplete due to the “short” period of time after the disasters, insufficient and controversial data, difficulties to adequately assess longer term implications, etc. More future studies are necessary to evaluate and update the “known” agricultural and food impacts of the disasters and further in depth “micro” studies are needed to fully understand and estimate diverse impacts of the disasters in each location and community, type of farms and productions, and component of agri-food chain.

References:

Bachev, H. and F. Ito (2013). Impacts of Fukushima Nuclear Disaster on Agri-Food Chains in Japan. - The IUP Journal of Supply Chain Management, X(4).

Bachev, H. and F. Ito (2015). March 2011 Earthquake, Tsunami, and Fukushima Nuclear Disaster. Impacts on Japanese Agriculture and Food Sector. LAP LAMBERT Academic Publishing.

Belyakov, A. (2015). From Chernobyl to Fukushima: an interdisciplinary framework for managing and communicating food security risks after nuclear plant accidents. - Journal of Environmental Studies and Sciences, 5 (3), p. 404-417.

Fujita, M., H. Nobuaki, J. Sagara, B. Adam (2012). The economics of disaster risk, risk management, and risk financing. Economic Impacts, IBRD-World Bank.

Futahira, S. (2013). Nuclear power plant accident and recovery of fishery. Presentation at the JA Conference in Fukushima, May 18.

Koyama, R. (2013). The Influence and Damage caused by the Nuclear Disaster on Fukushima's Agriculture. Nuclear Disaster on Fukushima's Agriculture, 商学論集 第81 巻第4.

Nakanishi, T. and K. Tanoi (eds.). (2013). Agricultural Implications of the Fukushima Nuclear Accident, Springer.

Pushpalal, D., Z. Yan, T. Thi, Y. Scherbak and M. Kohama (2013). Tears of Namie: An appraisal of Human Security of Township of Nanmie. Conference proceedings, UNU-EHS, Bonn.

Todo, Y., K. Nakajima and P. Matous (2015). How Do Supply Chain Networks Affect the Resilience of Firms to Natural Disasters? Evidence from the Great East Japan Eeartquake. - Journal of Regional Science, 55(2), p. 209–229.

Tsuboi, N. (2015). Large-scale Study on the Effects on Agriculture and Food Industry in Japan from the Natural Calamility in March 2011. - Economic Tought, N 3, p. 147-150 (*in Bulgarian*).

Ujiie, K. (2012). Japanese Consumer Evaluation of Radioactive Contamination on Food: Rationality and Emotion (provided by author).

Watanabe, A. (2011). Agricultural Impact of the Nuclear Accidents in Fukushima: The Case of Ibaraki Prefecture. – In: Disaster, Infrastructure and Society Learning from the 2011 Earthquake in Japan, p. 291-298,

Watanabe, N. (2013). Current State of Losses from the Nuclear Accident and Support Measures by JA-Affiliated Organizations. Norinchikin Research Institute.

BCJ (2013). Impact of the Great East Japan Earthquake on the Natural Environment in Tohoku Coastal Regions. Biodiversity Center of Japan. Ministry Environment.

CAA (2014). Survey of Reception of Health Risk of Agri-food Products. Consumer Affairs Agency.

GJ (2012). Road to Recovery. Government of Japan, March.

CS (2014). Fresh breeze of Change in Agriculture Starts Here. City of Sendai.

JA-ZENCHU (2011). Recovery and Reconstruction by Rower of Cooperation. Central Union of Cooperatives.

JFC (2011-2013). Findings on impact of earthquake on food industry. Japan Finance Corporation, July (in Japanese).

JFC (2011-2013). Findings of the impact of the Great East Japan Earthquake has given to farm management. August 2011 survey.

JFC (2011-2014). Consumer Survey results on changes in purchasing behavior of consumers after Earthquake. July 2011 survey.

JMA (2014). Information on the 2011 off the Pacific Coast of Tohoku Earthquake. Japan Meteorological Agency.

IAEA (2011). IAEA international fact finding expert mission of the Fukushima dai-ichi npp accident following the great East Japan earthquake and tsunami. International Atomic Energy Agency, June.

IBRD (2012). The Great East Japan Earthquake. Learning from Megadisasters. Washington D.C.: International Bank for Reconstruction and Development.

MAFF (2012-2014). Business resumption status of agricultural management entities in disaster prefectures. Ministry of Agriculture, Forestry and Fisheries, February 1, 2014.

MEXT (2011). Survey on the Movement of Radioactive Substances in River Water and Well Water. Ministry of Education, Culture, Sports, Science and Technology, October.

MHLW (2013). Survey of Dietary Intake of Radionuclides (September to October 2012). Ministry of Health, Labor and Welfare, June 21.

MHLW (2014). Levels of Radioactive Contaminants in Foods Tested in Respective Prefectures. Ministry of Health, Labor and Welfare, December 5.

NISA (2011). Seismic Damage Information. The 110th Release. Nuclear and Industrial Safely Agency, 23 April.

NIRA (2013). Status of Recovery and Current Problems in Three Disaster-hit Prefectures. What the Data Tells Us Indexes for Recovery and Reconstruction following the Great East Japan Earthquake. National Institute for Research Advancement.

NPA (2016): Updates on damages from Great East-Japan Eearthquake, National Police Agency.

OECD (2013). OECD Economic Surveys Japan. Paris: The Organization for Economic Co-operation and Development.

RA (2014). Efforts and the current state of reconstruction. Reconstruction Agency, 26 August.

TEPCO (2011-2014). Press Release. Tokyo Electric Power Company.

UFJ (2011). The Economic Impacts of the Great Eastern Japan Earthquake: A Supply-Side Analysis. - UFJ Economic Review, Vol 6, N 3.

UN Scientific Committee on the Effects of Atomic Radiation (2014). UNSCEAR 2013 Report. Sources, Effects and Risks of Ionizing Radiation. New York.

WHO (2013). Health risk assessment from the nuclear accident after the 2011 Great East Japan Earthquake and Tsunami, based on a preliminary dose estimation. World Health Organization.

WWF (2013). Japan Report on the Nature and Livelihood Recovery Project, A prelim assessment of ecological and social-economic changes in selected areas affected by the Great East Japan Earthquake, 2011. World Wide Fund.

6.X.2015