Agri-food sector impact of March 2011 earthquake and tsunami in Northeastern Japan

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Abstract Dispite intensive multidiciplinary research the overall impact of the March 2011 earthquake, tsunami and Fukushima nuclear accident on Japanese agri-food sector is far from being completely evaluated. That is a conccquence of the scale of triple disaster and affected agents, the effects’ multiplicities, spillovers, and long time horizon, the lack of “full” information and models of analysis, on-going challenges with post disaster recovery and reconstruction, etc. This paper presents research findings on multiple impacts of the March 2011 earthquake and tsunami on Japaneses agriculture and food sector. First, disaster events and their effects is outlined; next the impacts on agri-food organizations, products, markets and consumers are evaluated; finally, specific and overall short-term and long-term impacts on agriculture, food industries and food consumption in different parts of the country is assessed. The study is based on a wide range of information from diverse organizations as well as original experts assessments of leading experts in the area. Agriculture, food industry and food consumption have been among the worst hit by the disasters areas. There is a great variation of the specific and combined impacts of disasters on different type of farming and business enterprises, particular agents, individual sub-sectors, and specific locations. Disasters have also had positive impacts on the development of certain sectors in the most affected regions and some sectors in other parts of the country as post disaster reconstruction have 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. More future studies are necessary to evaluate and update the “known” agricultural and food impacts as further in depth “micro” studies are needed to fully understand the impacts of the disasters in each location and community, type of farms and productions, and component of agri-food chain.

Keywords: Agriculture, Food industry, Food consumption, March 2011 earthquake, tsunami, nuclear accident, Japan, Socio-economic impacts

Introduction

On March 11, 2011 the strongest ever recorded in Japan earthquake occurred which triggered a powerful tsunami and caused a nuclear accident in one of the world’s largest nuclear plant. The 2011 disasters have had immense impacts on people life, health and property, social infrastructure and economy, natural and institutional environment, etc. in North-eastern Japan and beyond.

There have been numerous publications on diverse impacts of the 2011 disasters including on the Japanese agriculture and food sector [1,2,3,4,5,6,7]. 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 challenges with post disaster recovery and reconstruction, etc. the overall impacts of 2011 disasters on Japanese agri-food sector is far from being completely evaluated.

In our previous publications we have presented our study on impacts of Fukushima nuclear disaster on Japanese agri-food chains[8,9]. This paper assesses the impacts of the March 2011 earthquake and tsunami on the Japanese agriculture and food sector. This research has been financialy supported by the Japan Foundation.

Description of events and effects

On March 11, 2011 a mega thrust with a magnitude of 9.0 Mw occurred off the Pacific coast of Japan. The earthquake triggered powerful tsunamis that spread over the wide area from Hokkaido to Okinawa. According to estimates an extensive coastal area surpassing 400 km was hit by tsunami higher than 10 m that submerged plane areas more than 5 km inland. The tsunami inundated a total area of approximately 561 km² or 4.53% of the total territories of the six Northeastern prefectures of Honshu Island. The most affected was Miyagi prefecture where 16.3% of the territory was flooded by seawaters.

The 14 meter high tsunami overwhelmed seawalls of the Fukushima Daiichi Nuclear Power Plant, damaged cooling and control systems, and caused level 7 meltdowns[10]. The later lead to releases of huge radioactivity and contamination of environment, property
and infrastructure in Fukushima and neighboring prefectures.

The earthquake, tsunami and the nuclear accident caused a large evacuation involving some 470,000 and over 320,000 displaced persons on a longer-term basis\[11\]. The greatest number of evacuees and stranded persons 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 more than 247,000 evacuated people living in temporary housing and other makeshift facilities nationwide\[11\].

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. \[12\].

The March 2011 disasters have caused immense damages in North-eastern Japan and beyond. The latest figure shows that 1,220,360 buildings in 20 prefectures have been damaged from the earthquake and tsunami, out of which 10.43% totally collapsed, 22.35% half destroyed, and the rest partially damaged, flooded or burned down\[13\]. In addition, there were reports for numerous damaged roads, bridges, dikes, railways and landslides in 14 prefectures. The biggest property damages have been registered in Miyagi, Fukushima, Ibaraki, and Iwate prefectures.

The triple disaster has casued destruction of many businesses, which incurred big direct and indirect losses in certain sectors (manufacturing, energy, transport, agriculture etc.) and supply chains in Japan and worldwide\[14, 15, 16, 17\]. Furthermore, enormous amount of rubble and debris have been created by the earthquake and tsunami. In affected 239 municipalities of 13 prefectures the total amount of disaster debris is estimated to be about 20 million tons and tsunami deposits around 10 million tons\[11\].

The initial official estimate for the direct economic losses from the March 2011 disaster was about 16.9 trillion yen ($210 billion USD) or 4% of the Gross Domestic Product of Japan (Government of Japan, 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.

There has been a huge government budget for recovery, reconstructions, compensations and development \[1\]. Subsequently, there has been a sizeable or complete recovery of damaged infrastructure in the months after the disaster\[11\]. Nevertheless, there has been unlike speed in the infrastructure recovery in different parts of affected regions as well as of individual sectors of economy and social life\[11,18\].

The process of reconstructions has been associated with number of challenges such as: failure for timely evacuation from certain areas, slow response of authorities, lack of sufficient public information in 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 eclectic power, increasing energy supply costs, revisions in national energy, disaster prevention etc. policies, etc. \[12\].

**Affected farms and agricultural resources**

There have been a huge number of destructed agricultural communities, farms, and agricultural lands and properties from the March 2011 disasters. The total number of damaged Agricultural Management Entities of different type (private farms, corporate entities, cooperatives, local public bodies, etc.) reached 37,700 or around 16% of all Agricultural Management Entities in the affected eight prefectures (Table 1). The greatest part of damaged farms (45.6%) was in Fukushima prefectures where more than a third of farms were hurt by the earthquake, tsunami, or nuclear accident. Tsunami affected adversely almost 5% of all farms of the six coastal prefectures. Tsunami damaged Agricultural Management Entities account for about 27% of all damaged by the disasters entities. The majority of the

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1 Government approved two supplementary budgets of 6.14 trillion yens for relief and recovery, and launched a ten-year reconstruction program (for Fukushima, Miyagi and Iwate prefectures) of 25 trillion yens for the period 2011-2015\[11\].
tsunami-damaged farms are located in Miyagi (59.4%) and Fukushima (26.9%) prefectures.

Reported area of agricultural land damaged by the 2011 disasters in the six coastal and six inland prefectures is around 24,500 ha (Table 2). More than 85% of the washed away or flooded by the tsunami farmlands were paddy fields. The mostly hit farmlands were in Miyagi and Fukushima, where affected farmlands amount almost to 11% and 4% of total farmland.

Table 1. Number of damaged Agricultural Management Entities by 2011 earthquake (March 11, 2012)

<table>
<thead>
<tr>
<th>Prefectures</th>
<th>Total number of Agricultural management entities*</th>
<th>Damaged agricultural entities</th>
<th>Entities damaged by tsunami</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Share, %</td>
<td>Number</td>
</tr>
<tr>
<td>Aomori</td>
<td>3,733</td>
<td>180</td>
<td>170</td>
</tr>
<tr>
<td>Iwate</td>
<td>35,321</td>
<td>7,700</td>
<td>480</td>
</tr>
<tr>
<td>Miyagi</td>
<td>47,574</td>
<td>7,290</td>
<td>6,060</td>
</tr>
<tr>
<td>Fukushima</td>
<td>50,945</td>
<td>17,200</td>
<td>2,850</td>
</tr>
<tr>
<td>Ibaraki</td>
<td>56,537</td>
<td>1,430</td>
<td>180</td>
</tr>
<tr>
<td>Tochigi</td>
<td>25,010</td>
<td>1,330</td>
<td>-</td>
</tr>
<tr>
<td>Chiba</td>
<td>17,224</td>
<td>1,220</td>
<td>430</td>
</tr>
<tr>
<td>Nigata</td>
<td>5,311</td>
<td>1,190</td>
<td>-</td>
</tr>
<tr>
<td>Nagano</td>
<td>312</td>
<td>210</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>241,967</td>
<td>37,700</td>
<td>10,200</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture, Forestry and Fisheries

*subject to status confirmation

Table 2. Area of damaged agricultural land by the 2011 earthquake (March 11, 2012)

<table>
<thead>
<tr>
<th>Prefectures</th>
<th>Damaged agricultural land</th>
<th>Tsunami damaged agricultural land</th>
<th>Share of completely restored agricultural land (%)</th>
<th>Share of restored tsunami damaged land (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (ha)</td>
<td>% in total cultivated land</td>
<td>Area (ha)</td>
<td>% in damaged land</td>
</tr>
<tr>
<td>Aomori</td>
<td>107</td>
<td>0.1</td>
<td>77</td>
<td>72</td>
</tr>
<tr>
<td>Iwate</td>
<td>1,209</td>
<td>0.8</td>
<td>725</td>
<td>60</td>
</tr>
<tr>
<td>Miyagi</td>
<td>14,558</td>
<td>10.7</td>
<td>14,341</td>
<td>98.5</td>
</tr>
<tr>
<td>Fukushima</td>
<td>5,927</td>
<td>3.9</td>
<td>5,462</td>
<td>92.1</td>
</tr>
<tr>
<td>Ibaraki</td>
<td>1,063</td>
<td>0.6</td>
<td>208</td>
<td>19.6</td>
</tr>
<tr>
<td>Chiba</td>
<td>1,162</td>
<td>0.9</td>
<td>663</td>
<td>57.1</td>
</tr>
<tr>
<td><strong>Total coastal</strong></td>
<td>24,026</td>
<td>2.7</td>
<td>21,476</td>
<td>89.4</td>
</tr>
<tr>
<td>Yamagata</td>
<td>1</td>
<td>0.0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Tochigi</td>
<td>198</td>
<td>0.1</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Gunma</td>
<td>1</td>
<td>0.0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Saitama</td>
<td>39</td>
<td>0.0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Niigata</td>
<td>117</td>
<td>0.1</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Nagano</td>
<td>95</td>
<td>0.1</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total inland</strong></td>
<td>451</td>
<td>0.1</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>24,477</td>
<td>1.6</td>
<td>21,476</td>
<td>87.7</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture, Forestry and Fisheries

There have been registered damages in 36,092 places including: damaged agricultural land in 18,186 areas, damaged agricultural facilities (mainly storage reservoirs, drains, pumps, shore protection facilities for agricultural land) in 17,317 points, damaged coastal protection facilities for agricultural land in 139 points, and damaged facilities for daily life in farming villages (mainly community sewerage) in 450 points[19]. The biggest number of places with damaged lands was registered in Iwate (73.9%), Fukushima (10%) and Miyagi (8.3%) prefectures[19]. There has been also enormous destruction of livestock, fruit trees and crops in affected by the disasters regions. The total crop and livestock damages from the 2011 earthquake are estimated to worth 14.2 billion yen[2].

The official estimate for the inflicted damage on agriculture by the 2011 earthquake is 904.9 billion yen (Figure 1). 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. (mainly country elevators, agricultural warehouses, PVC greenhouses, livestock bams, compost depos), and agricultural crop and livestock etc. The greatest amount of damage has incurred in Miyagi prefecture representing 56.5% of the total worth.
A survey on economic situation of agricultural management entities in the tsunami damaged areas have found out that in 2011 the sales revenues from agricultural products dropped by 68% comparing to 2010 and the agricultural income by 77%\[^2\]. The biggest decrease in sales and income experienced farmers in Miyagi prefecture, followed by producers in Iwate and Fukushima prefectures (Figure 2). Severe blows on sales and income were registered by producers in the three dominant type of farming in the region as those specialized mainly in facilities vegetables saw the highest decrease in sales and income (86% and 76% accordingly), followed by the rice and open field vegetable producers (Figure 3). There have been some improvements of sales and incomes in all areas as the fastest recovery has been registered in Miyagi farms’ sales and income. The slower growth of income compared to sales in Iwate and Fukushima prefectures was due to higher costs associated with the post-disaster cleaning and rebuilding. The fastest income growth was registered by rice producers due to restoration of farmland and augmentation of sales. 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\[^{19}\].

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. According to a survey disaster affected negatively almost 55% of Japanese farms (Figure 4). A 2012 survey has found out that the most severely affected have been farmers in Tohoku and Kanto regions. In the worst hit Iwate, Miyagi, Fukushima, Ibaraki, Tochigi, Gunma, and Chiba prefectures more than 88 89% of all farms “are still affected” or “were affected in the past” from the earthquake, tsunami and nuclear accident.

What is more, 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 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 of the earthquake, tsunami and nuclear accident.

Among different sectors of agriculture the most farms have been affected by the disasters in beef and facility flowers production (Figure 5).
Figure 3. Evolution of agricultural sale and income of agricultural management entities with different specialization in tsunami-damaged areas (2010=100)
Source: Ministry of Agriculture, Forestry and Fisheries, 2013

Figure 4. Adverse effect of Great East Japan Earthquake on farm management in different regions of Japan (March 2012)
Source: Japan Finance Corporation

Figure 5. Adverse effect of Great East Japan Earthquake on farm management in different subsectors of Japanese agriculture (March 2012)
Source: Japan Finance Corporation

Table 3. Reasons for those who are currently adversely affected in different regions (August, 2011; January 2012)*

<table>
<thead>
<tr>
<th></th>
<th>Damage to production</th>
<th>Damage input supply</th>
<th>Damage to distribution</th>
<th>Decline in sell prices</th>
<th>Harmful rumors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>24.5</td>
<td>23.2</td>
<td>41</td>
<td>27.1</td>
<td>44.4</td>
</tr>
<tr>
<td>Hokkaido</td>
<td>12.6</td>
<td>14.1</td>
<td>55.9</td>
<td>39.7</td>
<td>34.4</td>
</tr>
<tr>
<td>Tohoku</td>
<td>46.3</td>
<td>38.2</td>
<td>51.5</td>
<td>25.2</td>
<td>60.8</td>
</tr>
<tr>
<td>Kanto</td>
<td>34.1</td>
<td>26.1</td>
<td>28.8</td>
<td>17.6</td>
<td>45.2</td>
</tr>
<tr>
<td>Hokuriko</td>
<td>12.4</td>
<td>14.8</td>
<td>47.6</td>
<td>29.6</td>
<td>40</td>
</tr>
</tbody>
</table>
There are also huge differences in the most affected sectors in different regions of the country. One year after disasters 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. On the other hand, in Ibaraki, Tochigi, Gunma, and Chiba prefectures the negative impact lasted longer for the significant number of beef, mushroom, dairy, and open field vegetables producers.

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 3). What is more, for farmers still affected by the disasters the importance of the first two factors increased considerably in 2012 comparing to the disaster year. There has been a great variation in the importance of different factors affecting producers in individual sectors of agriculture. For instance, “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. Furthermore, in 2012 the impact reduced sell prices further increased for most subsectors, while of the harmful rumors for all producers.

Ministry of Agriculture Forestry and Fisheries worked out a “Strategy for the Revitalization of the Agriculture, Forestry, and Fisheries”[12] aiming to rapid restoration and resuming of farming in disaster affected regions. Consequently, 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-affected farmland was cleaned of rubble, a large part of agricultural infrastructure reconstructed[8]. Consequently, 79% of all damaged farms in 9 prefectures and 40.2% of tsunami damaged farms in 6 prefectures and 40% of resumed farming (Figure 6).

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)[19]. That was close to the target in the 3 years plan for complete restoration of tsunami-damaged farming set by the Basic Guidelines for Reconstruction of Agriculture and Rural Communities after the Great East Japan Earthquake. Consequently, a half of the affected by the tsunami farms resumed agricultural production or preparations for it[19].

The latest figures indicate that 63% of tsunami damaged agricultural land has been made again available for farming[11], and more than 55% of the affected farms resumed operation. In the worst hit areas the biggest progress in restoration of the damaged farms has been achieved in Iwate prefecture and for the tsunami damaged farms in Miyagi prefecture. Nevertheless, despite that agricultural land in Miyagi prefecture was planed to be fully recovered by 2015, the officials announced that in might be delayed by a few more 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 resumeable for farming. 82.3% of damaged agricultural facilities have been restored, and 60.9% of agricultural management entities resume operations[19].

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 7). Moreover, importance of most of these factors has been decreasing due to progression in reconstruction, returning of evacuees, restoration of farmlands and public support measures. On the other hand, the significance the nuclear crisis as a reason deterring effective resumption of operations by majority of farms has been increasing.

Most critical factors for “not resuming farming” for majority of farms in Iwate and Miyagi prefectures have been unavailable arable land and facilities (Figure 8). Other important factors for a significant number of farms in these prefectures are that farmers have still not decided on the place of settlement (afflicting 60% of damaged farms in Iwate prefecture), funding of farming activities is an issue, and equipment can not be secured. On the other hand, the most important obstacle to restart operations for the most Fukushima farmers has been the “impact of nuclear accident”.

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 debris cleaning and soil restoration, emergency aid, agri-food safety, production recovery and modernization, product and technologies innovations and diversification, agri-food marketing, reconstructing of business and infrastructure, other public and private research and development projects. All they 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.

<table>
<thead>
<tr>
<th>Prefecture</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tokai</td>
<td>7.6</td>
<td>7.3</td>
<td>30.5</td>
<td>18.2</td>
<td>41.9</td>
</tr>
<tr>
<td>Kinki</td>
<td>5.4</td>
<td>11.4</td>
<td>25</td>
<td>28.6</td>
<td>29.3</td>
</tr>
<tr>
<td>Chugoku-Shikoku</td>
<td>6.3</td>
<td>9.7</td>
<td>31.7</td>
<td>23.9</td>
<td>33.7</td>
</tr>
<tr>
<td>Kyushu</td>
<td>8.6</td>
<td>9.1</td>
<td>27.9</td>
<td>29.9</td>
<td>40.5</td>
</tr>
</tbody>
</table>

Source: Japan Finance Corporation

*multiple answers*
MAFF launched the National specific disaster restoration programs for farmlands and farming facilities which is implemented to enlarge partitions for farmlands to achieve economies of scale and farming efficiency. For instance, the East Sendai District Farmland Consolidation Project covers 1,979 ha out of the 2,244 ha of the total District area as the ratio of consent by the landlords for farmland consolidation is 94.6%[20].

According to experts there are many wanting to lease in abandoned farmland and start large-scale corporate farming. That will let consolidate and enlarge farm size, introduces large-scale machineries and innovations, explore economies of scale and scope, increase investment and efficiency, diversify and improve competitiveness of farming enterprises.

The 2011 disaster has induced further expansion of a “no-soil” factories in Japan which has been perceived as an efficient way to overcome some of major challenges associated with the post-disaster recovery in the affected regions – degraded (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 (originated in Japan) 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 have been also experimented – e.g. production of clean bio-energy. Increasing applications of ICT in agriculture have been also reported leading to precision technologies, higher farming productivity, efficient use of resources, enhanced food safety, and improved relations with counterparts and consumers.

In the years after the nuclear accident an increase interests in renewable energy introduction has been reported, including in the sector “Agriculture”. In most affected regions and nationwide the later has been motivated by the new opportunities of development (including Government support measures) as well as souring costs of energy supply. Recent survey has found that 11.6% of the Agricultural Management Entities 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[21]. 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 greatest number of agricultural producers who use, plan to or are interested in introduction of renewable energy in all regions of the country. 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 a 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.

Figure 6. Share of agricultural management entities, which resumed farming (percent)

Source: Ministry of Agriculture, Forestry and Fisheries

Figure 7. Reasons for not resuming farming in Iwate, Miyagi and Fukushima prefectures, multiple answers (% of farms)

Source: Ministry of Agriculture, Forestry and Fisheries, 2014
Impact on food industries

After March 2011 the food industry in the disaster regions and throughout the country was also seriously affected by the production drops, business suspensions, distribution ruptures, etc. due to damaged plants, rolling blackouts, packaging material production shortages, gasoline shortfalls, etc. [2].

Regular surveys on food industries dynamics reviled 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 (Figure 9). 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. What is more, a significant share of food industry was not still recover from the disaster by the end of that year in Iwate, Miyagi and Fukushima prefectures and Northern Kanto region.

In 2011 the most common reasons for the negative impact of the triple disasters was the reduction in sales volume, increase in the price of ingredients and materials, and the decrease in the demand and number of costumers. There has been also reported a great variation of the individual factors for the adverse impact of nuclear accident in different regions of the country.

There is also difference in the adverse impact in different subsectors of food industry. 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 good number of food industry companies. Disasters affected uniformly strong 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 Restaurants business.
Effects on markets and consumers' behavior

In the days after the 2011 disasters there was destruction of supply of potable water, foods and other necessities in most affected regions[2]. What is more, food shortages spread beyond the worst affected areas as many people were panic buying after the nuclear crisis. Unprecedented for the post war period situation of food rationing and empty stores shelves were prevailing in the days after the crisis across the disaster areas and big cities like Tokyo (Figure 10). The Government implemented swift measures to procure and provide emergency food, beverages, fuel etc., and rapidly restored damaged agricultural, fishery and food production and distribution facilities[3].

“Normal” food supply to all affected by the disasters people was quickly restored and important infrastructure (production and storage facilities, wholesale markets, transportation network etc.) rebuilt. Nevertheless, there have been numerous restrictions on production, sells, shipments and consumption of basic agricultural and food products in the affected by the nuclear accident regions. Furthermore, due to genuine or perceived health risk many consumers stop buying agricultural, fishery and food products originated from the affected by the nuclear accident regions. Even in cases when it was proven that food is safe some wholesale traders, processors and consumers restrain buying products from the contaminated areas[2,3,6,7,22]. Consequently, the demand for many traditional farm produces from the affected by nuclear accident regions (such as rice, fruits, vegetables, mushrooms, milk, butter, beef etc.) significantly declined while prices considerably decreased.

Some experts argue that both producers and consumers are victims of the “reputation damage”[3]. According to 2013 survey 26.1% of the consumers do not even know that inspections of radioactive contamination are being conducted[3]. In order to facilitate communication with consumers, promote and recover Fukushima agricultural products numerous initiatives have been undertaken by farmers, agricultural organizations, NGOs, authorities, business, retailers etc. such as: direct sells 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.

Data show that in 2011 the daily intake per person for some of the most likely affected by the nuclear disaster food groups decreased comparing to the period before the accident – e.g. consumption of mushrooms dropped by 12.5%, seaweeds by 5.4%, pulses by 6.5%, etc.[8]. That change in the national consumption pattern is probably a consequence of the newly emerged consumers risk concern, higher procurement costs or other (unspecified) reasons.

There has been significant change in the purchase behavior of a great number of consumers after the March 2011 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.[24]. On the other hand, there is an increase in purchase mineral water (17.6%). These changes were more dynamic in the worst affected East Japan than in the other parts of the country.

In the months after the earthquake, 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”. However, for majority of consumers there was not change of place to buy fresh (88.5%) and processed (89.1%) food comparing to the pre-duster period[24].

Recent data indicate that a good portion of Japanese consumers (36.5%) “often” or “sometimes” purchase foodstuffs from affected by the 2011 disasters areas (Figure 11). The latest figure is much higher in Tohoku region then in the other parts of the country.

There are also gender and age differences in willingness to buy from the affected regions. For instance, older generation and women tend to buy more from the affected regions than the younger generation and men[24]. Nevertheless, for a great proportion of the consumers it is important to select the region of agro-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[25]. For most Japanese consumers who do not want to purchase food stuff from the affected regions even if there is 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[25]. Furthermore, 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 Tohoku and Kanto regions), while 7.9% kept after the disaster but currently not (much higher in Tohoku region).

Figure 10. Stores with over-the-counter rice inventories in Tokyo and its vicinity (percent)

Source: Ministry of Agriculture, Forestry and Fisheries
Expert assessments on impacts and factors of March 2011 disasters

In order to expend the analysis we organized an expert assessments to identify the 2011 disasters’ short and longer terms impacts on agriculture, food industries and consumers as well as factors for persistence of negative impacts, and longer-term impacts on major resources, productions, organizations, efficiency, etc. in different regions of the country. The expertise was carried out in October-November 2014 and included 11 experts – all leading researchers in the area (five from the Tohoku University, one from the Tsukuba University, and five from the Policy Research Institute, Ministry of Agriculture, Forestry and Fisheries).

Specific impacts of earthquake

The specific short-term impact of the earthquake on agriculture in Miyagi and Fukushima prefectures is significant negative according to most experts (Figure 12). In Iwate prefecture the greatest part of the experts believe that impact is moderate negative, while in Aomori, Chiba and Ibaraki prefectures the effect is assessed as insignificant negative. The specific short-term impact of the earthquake on agriculture in other parts of the country is evaluated either as insignificant or none. At the same time no expert believes there is a positive specific or combined short or long-term impact on the 2011 disasters on agriculture in Japan.

The specific short-term impact of the earthquake on food industries in Aomori, Ibaraki, Chiba prefectures and the rest Japan is predominately evaluated as insignificant negative. No expert indicates that there is a positive specific short or long-term impact on the 2011 disasters on food industries in Japan.

The majority of experts think that the specific short-term impact of the earthquake on food consumption in Fukushima, Miyagi and Iwate prefectures has been significant or moderate negative (Figure 14). For Aomori and Ibaraki prefectures a half of the experts evaluate that impact as significant or moderate negative while another half as insignificant negative or none. The specific short-term impact of the earthquake on food consumption in Chiba prefecture and the rest of the country are assessed mostly as insignificant negative or none. No expert believes there is a positive specific or combined short or long-term impact of the 2011 disasters on food consumption in Japan.

According to the majority of experts there will be no specific long-term impact of the 2011 earthquake on agriculture in Aomori, Ibaraki, and Chiba prefectures, and other parts of Japan (Figure 15). Most experts estimate that effect is significant negative or moderate for Miyagi prefecture, and insignificant negative for Iwate prefecture. The greatest part of the experts believes there will be some negative long-term impact on Fukushima agriculture but they are divided on its significance.

The bulk of experts estimate there will be no specific long-term impact of the earthquake on food industries in Aomori, Iwate, Ibaraki, and Chiba prefectures, and other parts of Japan (Figure 16). In Miyagi and Fukushima prefectures most experts foresee some negative long-term impact predominately evaluated as moderate and insignificant.

The majority of experts predict there will be no specific long-term impact of the earthquake on food consumption in Aomori, Ibaraki, and Chiba prefectures, and other parts of Japan (Figure 17). For Fukushima prefectures most expert expect some (moderate and insignificant) negative impact from the earthquake on food consumption, while for Iwate and Miyagi prefectures they are divided between certain negative implications and none.

2 All of them assessed the impacts on agriculture, nine assessed the impact on food industry, and ten assessed the impact on food consumption.
Specific impacts of tsunami

The greatest majority of the experts assess the short-term adverse impact of the tsunami on agriculture of Miyagi and Fukushima prefectures as significant, as moderate in Iwate prefecture, and as insignificant in Aomori, Chiba and Ibaraki prefectures (Figure 12).

The specific negative short-term impact of the tsunami on food industries in Miyagi, Fukushima and Iwate prefectures is evaluated as significant (Figure 13). In Aomori prefecture that effects is mostly ranged to be moderate while in Ibaraki and Chiba prefectures and the rest of Japan insignificant.

Most experts estimate there is a negative short-term impact of the tsunami on food industries in Miyagi, Fukushima and Iwate prefectures is evaluated as significant (Figure 13). In Aomori prefecture that effects is mostly ranged to be moderate while in Ibaraki and Chiba prefectures and the rest of Japan insignificant.

Most experts estimate there is a negative short-term impact of the tsunami on food consumption in all affected prefectures (Figure 14). The later is mostly described as significant in Miyagi prefecture, significant or moderate in Fukushima prefecture, insignificant in Ibaraki prefecture, and insignificant or moderate in Aomori, Iwate and Chiba prefectures. Despite that majority of experts indicate there is not adverse impact on food consumption in the rest of Japan, 40% of them see certain negative impact (mostly insignificant).

According to the biggest part of the experts there will be a significant long-term impact of the tsunami on agriculture in Miyagi and Fukushima prefectures (Figure 15). Most of them assess that effect to be insignificant for Iwate and Ibaraki agriculture. Nevertheless, a good portion of the panel evaluates as moderate the adverse long-term impact of that disaster on Iwate agriculture. The majority of experts do not perceive any long-term impact for Aomori and Chiba prefectures, and the rest of the country. Nevertheless, a good segment of them believe there will be negative (mostly insignificant) long-term impact on Aomori agriculture.

The greatest proportion of experts evaluate that there will be a significant negative long-term impact of the tsunami on food industries in Fukushima, Miyagi and Iwate prefectures, and a moderate one in Ibaraki prefecture (Figure 16). Most experts expect the negative long-term effect to be insignificant in Chiba and Aomori prefectures. Nevertheless, a third of them still foresee a stronger adverse impact (mostly moderate) in the later two prefectures. While the majority of panel predicts no long-term implications on food industries in other parts of Japan, every third one believes there will be some insignificant negative impact.

The majority of experts predict there will be no specific long-term impact of the tsunami on food consumption in Ibaraki and Chiba prefectures, and other parts of Japan (Figure 17). In other four affected prefectures it is expected to be some negative longer-term impacts on food consumption mainly evaluated as moderate in Miyagi and Iwate prefectures, and insignificant in Aomori and Fukushima prefectures.

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Figure 12. Short-term impacts of March 2011 disasters on agriculture in Japan

Source: assessment by panel of experts, 2014
Figure 13. Short-term impacts of March 2011 disasters on food industries in Japan

Source: assessment by panel of experts, 2014

Figure 14. Short-term impacts of March 2011 disasters on food consumption in Japan
Source: assessment by panel of experts, 2014

**Figure 15.** Long-term impacts of March 2011 disasters on agriculture in Japan

Source: assessment by panel of experts, 2014

**Figure 16.** Long-term impacts of March 2011 disasters on food industries in Japan

Source: assessment by panel of experts, 2014
Figure 17. Long-term impacts of March 2011 disasters on food consumption in Japan
Source: assessment by panel of experts, 2014

<table>
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<th>Table 5. Most badly affected areas from March 2011 disasters</th>
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<tr>
<td>Regions</td>
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<td>Chiba prefecture</td>
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<td>Other parts of Japan</td>
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Source: assessment by panel of experts, 2014  * frequency of listing
Combined impacts of 2011 disasters

The combined short-term impact of the 2011 disasters on agriculture in all regions is negative. According to all experts the disasters’ overall short-term impact on Fukushima agriculture is significant negative (Figure 12). All experts also evaluate as significant or moderate the short-term impacts on Miyagi and Iwate agriculture (mostly scaled as significant). The adverse short-term implications on Ibaraki agriculture are predominately ranked as moderate. The negative short-term impact on agriculture of other regions is commonly evaluated as insignificant or moderate (mainly moderate in Chiba prefecture, and insignificant in Aomori prefecture and the other parts of Japan).

According to all experts the combined short-term impact of the 2011 disasters on food industries in all badly affected regions (but Aomori prefecture) is negative (Figure 13). There is a full consensus among experts on the severity of adverse effect on Fukushima food industries (significant). Most experts also assess as significant the negative impact on food industries in Miyagi, Iwate and Ibaraki prefectures. The short-term impact on food industries in Chiba prefecture is predominately evaluated as moderate, and in Aomori prefecture and the rest of the country as insignificant. Nevertheless, a good number of experts believe in a stronger (moderate and significant) negative impact in Aomori prefecture and the rest of the country. Furthermore, some experts think the 2011 disasters had a combined positive short-term impact on food industries in other parts of the country.

The experts also estimate that the combined short-term impact of the 2011 disasters on food consumption in all regions of the country has been negative (Figure 14). The food consumption in Fukushima prefecture has been most severely affected. The biggest part of the experts estimate that the adverse short term impact has been significant in all other prefectures but Aomori (mostly ranked as moderate).

Assessments of experts on the most badly affected by the 2011 disasters areas of agriculture, food industries and food consumption in different parts of the country are summarized in Table 5. Many experts have underlined that there are considerable differences in the impacts in major regions (like Tohoku, Kanto, rest of Japan) as well as among individual areas of each prefecture. Therefore, in depth studies for each area are necessary in order to better understand diverse impacts and factors of the disasters.

Furthermore, some experts have pointed out that the 2011 disasters added some complication to already existing problems like aging communities in rural areas. The lost community identity by many people, avoidance of Tohoku products, and labor scarcity in certain industries (e.g. marine), all they have been also highlighted by some experts.

One expert has commented that the March 2011 disasters hurt a lot the agri-food chain but some subsectors (like vegetable and fruit marketing) quickly restarted in Miyagi prefecture thanks to the small commercial shops (Yaoya). The later rapidly secured vegetables and fruits supply from local producers (on March 12, 2011) and proved that small size marketing business is much more resilient during a big disaster comparing to “highly efficient” large operators (supermarkets).

According to all experts there will be a significant negative long-term impact of the 2011 disasters on agriculture in Fukushima prefecture (Figure 15). The majority of experts also expect a significant impact on Miyagi agriculture and moderate one on Iwate agriculture. For Aomori and Ibaraki agriculture the majority of experts foresee insignificant long-term adverse implications. However, a good share among them believes there will be stronger long-term negative consequences in these two prefectures (especially Ibaraki). For Chiba agriculture the long-term negative impact is mainly juggled to be moderate, but a significant number of experts expect insignificant or none. While the bulk of experts do not project any long-term implication on agriculture in other parts of Japan, a good portion of them believe there will be some (mostly insignificant and moderate) negative impacts.

The greatest part of the experts estimate there will be a significant negative long-term impact of the 2011 disasters on food industries in Fukushima and Miyagi prefectures (Figure 16). Most of them also expect significant negative consequences on Iwate food industries, moderate one for Ibaraki prefecture, and insignificant in Aomori prefecture. Nevertheless, a good portion of the panel believes there will be no long-term implications for Ibaraki, Iwate and Aomori food industries. Most experts indicate they see no long-term consequences from the 2011 disasters for food industries in Chiba prefecture and other parts of Japan. However, many among them (the majority for Chiba prefecture, and a good portion for the rest of Japan) believe there will be some negative impacts on a longer run.

The majority of experts predict that the combined long-term impact of the 2011 disasters on food consumption in Fukushima prefecture will be significantly negative (Figure 17). While the greatest portion of the experts believes there will be some negative consequences (mostly moderate and insignificant) on food consumption in all regions of the country, many among them predict no effect at all.

Factors and long-term implications on agri-food sector development

In the longer term the mostly affected by the disasters areas of agri-food sector in Fukushima prefecture are likely to be: water resources, livestock, permanent crops, seasonal and annual crops, safety control, disaster prevention measures, relations with consumers, demand for region’s products, reputation of products and services, production structure, land resources, relations with buyers, agricultural cooperatives, viability of agricultural communities, rural infrastructure, labor, and sector’s export (Figure 18). The majority of experts evaluate the level of long-term effects in all these areas as high.

The greatest part of the experts also predicts there will be a considerable (moderate or high) long-term impact on product safety, willingness to enter that business, public support to the region, sustainability of middle enterprises, farming and business infrastructure, willingness to leave present business, income and profit, competitiveness,
management, material assets, relations with public authorities, public support to the sector, relations with community, relations with research and education, relations with suppliers, costs of doing business, sustainability of big enterprises, integration into supply chains, organizational structures, investment capability, and productivity of prefectural agri-food sector.

In the long-term the most severely affected by the disasters area of agri-food sector of Miyagi prefecture is land resources. The majority of experts also expect a moderate long-term effect on farming and business infrastructure, permanent crops, rural infrastructure, and production structure in the prefecture. The long-term impacts of the disasters on all other areas of agri-food sector are less important in this prefecture.

In Iwate prefecture a moderate long-term effect of the 2011 disasters on agri-food sector are expected for land resources, and farming and business infrastructure. The majority of experts foresee no significant implications for all other areas of agri-food sector in this prefecture.

For other parts of the country, a bigger part of the experts (over 18%) only envisage a high long-term effect of the 2011 disasters on disaster prevention measures, and a moderate one on sector’s export, safety control, willingness to leave present business, rural infrastructure, agricultural cooperatives, viability of agricultural communities, and disaster prevention measures.

According to the great majority of experts the most important factors for adverse effects’ continuation in the agri-food sector of Fukushima prefecture are: consumers unwillingness to buy, long time required for cleaning and restoration of lands, destruction of traditional communities, bad reputation, high radiation, slow restoration of infrastructure and services, insufficient support from the central government, bad communication, and health risk concerns (Figure 19).

More than a half of the experts also point out as critical factors for sustaining the negative impacts in the prefecture: the government bans on production and/or sells, low confidence in the official information, slow process of returning evacuees back to home places, unresolved permanent radiation waste storage issue, lack of labor, and lack of consensus in the local communities.

Furthermore, a good number of the experts also believe that crucial for maintaining the negative consequences in the prefecture has been: the insufficient support from the local authority, low prices of produces, lack of information, ineffective measures by the authorities, little preparedness of public authorities, dislocation of affected homes, farms and businesses, insufficient compensation, destruction of agrarian and business organizations, unwillingness to restart damaged farms and businesses, and insufficient cooperation with community.

According to the majority of the experts the most important factors for the persistence of negative impacts in agri-food sector of Miyagi prefecture are: the destruction of traditional communities, lack of consensus in the local communities, long time required for cleaning and restoration of lands, insufficient support from the central government, slow restoration of infrastructure and services, and lack of labor.

A good number of experts also underline as critical factors in this prefecture: the outdated system of land ownership registration, destruction of agrarian and business organizations, unwillingness to restart damaged farms and businesses, and insufficient cooperation with community.

The majority of the experts are convinced that the most important factors for the persistence of negative consequences from the 2011 disasters in Iwate agri-food sector are: the destruction of traditional communities, lack of labor, and lack of consensus in the local communities. In addition, numerous experts have pointed out the insufficient support from the central government, and slow restoration of infrastructure and services as important factors.

For other parts of the country the majority has identified no single factor. Nevertheless, more than 36% of experts estimate that the consumers unwillingness to buy has been an important factor, while more than 18% specify: the bad reputation, low confidence in the official information, lack of information, ineffective policies, and overall state of the Japanese economy.
Figure 18. Longer-term effects of March 2011 disasters on different aspects of agri-food sector in Fukushima prefecture

Source: assessment by panel of experts, 2014

Figure 19. Factors for persistence of negative impacts of March 2011 disasters on agri-food sector (percent)

Source: assessment by panel of experts, 2014
Conclusion

On the eve of the forth anniversary of the 2011 triple disaster a number of conclusions on the agricultural and food chain impacts could be made.

Agriculture, food industry and food consumption have been among the worst hit by the disasters areas. Agri-food sectors of Fukushima, Miyagi and Iwate prefectures have been particularly severely affected in the short and longer term. 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 (small-big scale, specialized, diversified, integrated), particular agents (producers, processors, distributors, consumers, community and public organizations), individual sub-sectors (rice, vegetables, beef), and specific locations (evacuation zone, seaside).

Many of the negative effects can hardly be adequately expressed in quantitative (e.g. monetary) terms. In addition, the 2011 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 certain (more resilient, adaptive) sectors in the most affected regions and some (traditional, prospective) 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 (e.g. energy, security) sectors, food safety information and inspection, technological and product innovation, jobs creation and investment, farmlands consolidation and enhancement, infrastructural amelioration, organizational restructuring, etc.

Research on multiple impacts of the March 2011 disasters is incomplete due to the “short” period of time after the disasters, insufficient and controversial data, difficulties to adequately assess longer term implications, etc. Therefore, more future studies are necessary to evaluate and update the “known” agricultural and food impacts. Besides, further in depth “micro” studies are needed to fully understand and estimate the impacts of the disasters in each location and community, type of farms and productions, and component of agri-food chain.

References