Disaster, Diversity and Emergency Preparation
L.I. Magnussen (Ed.)

doi:10.3233/NHSDP190026

Assessment of Preparedness and Agri-Food Impacts of Fukushima Nuclear Accident: Implications for Improvement of Disaster Risk Management

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Abstract. On March 11, 2011, the strongest earthquake ever recorded in Japan triggered a powerful tsunami and caused a nuclear accident at the Fukushima nuclear plant. That "man-made" disaster had immense effects on people's lives, health and property, infrastructure, supply chains, economy, policies, natural and institutional environment, and more. This chapter assesses the preparedness for and the agri-food impacts of the Fukushima nuclear disaster, identifies challenges in post-disaster recovery, and summarizes the lessons learned for improving disaster risk management. Japan was not well prepared for such a huge disaster, and the agri-food sector and consumption were among the worst-hit areas. The triple disaster was a rare but high-impact event; therefore it is necessary to "prepare for the unexpected". Risk assessment is to include diverse hazards and multiple effects of a likely disaster, it is to be discussed with all stakeholders, and measures must be taken to train for complex disasters. It is necessary to modernize property rights, regulations, safety standards, and norms, as well as to improve the capability and coordination of responsible public and private actors. It is important to set up mechanisms for effective public resource allocation and reduction of agents' costs. Different elements of the agri-food chain have dissimilar capabilities, requiring differential public support. There is a strong regional interdependency of agrarian, food, and rural assets (and damages), and it is important to properly locate risk and take prevention and recovery measures. Disaster response demonstrated the important role of small-scale farms and food organizations; high efficiency for private, market, and collective governance; and international cooperation. Before, during, and after a disaster, all available information from all sources is to be immediately publicized in understandable form through all means. Disasters provide an opportunity to discuss, introduce, and implement fundamental changes in policies relating to agriculture, the economy, regional governance, energy, and disaster management. It is important to learn from past experiences and make sure that lessons learned are not forgotten.

Keywords. Fukushima, nuclear accident, agri-food impact, risk management

1. Introduction

On March 11, 2011, an earthquake with a magnitude of 9 Mw occurred off the Pacific coast of Japan; it is known as the Great East Japan Earthquake (GEJE). The GEJE was the most powerful earthquake ever recorded in Japan, and one of the most powerful

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earthquakes in history [JMA, 2013]. GEJE triggered powerful tsunamis, hitting a coastal area of more than 400 km and submerging areas 5 km inland. The earthquake and tsunami caused a nuclear accident at one of the world's biggest nuclear power stations—Fukushima Daiichi Nuclear Power Plant, Fukushima prefecture. The tsunami arrived at the plant 50 minutes after the initial earthquake as a 14-meter-high wave that overwhelmed seawalls and damaged cooling and control systems. Three out of six reactors suffered explosions, and level 7 meltdowns occurred, releasing a large level of radioactivity into the environment [NRA, 2014]. Radioactive contamination spread though the air, rain, dust, water circulation, wildlife, garbage disposal, and transportation, and it affected soil, water, plants, animals, infrastructure, and the population.

The Fukushima nuclear accident (FNA) has had an immense impact on people's lives, health, and property, and on the social infrastructure, economy, policies, and natural and institutional environment in affected regions, Japan, and beyond [Akiyama et al., 2012; Al-Badri and Berends, 2013; Bachev, 2014; Barletta et al., 2016; Belyakov, 2015; Buesseler, 2014; Fujita et al., 2012; IBRD, 2012; IRSN, 2012; MHLW, 2013; Nomura and Hokugo, 2013; WHO, 2013]. Japanese agriculture, the food industry, and agri-food consumption were among the worst affected areas [Bachev and Ito, 2014, 2018; FAO/IAEA, 2018; Hamada and Ogino, 2012; JFC, 2011–2014; Johnson, 2011; Koyama, 2013; Kunii et al., 2018; Monma et al., 2015; Nakanishi and Tanoi, 2013; Nakanishi, 2018; Oka, 2012; Sekizawa, 2013; Todo et al., 2015; Ujiie, 2012; Watanabe, 2013]. However, there are still many issues and challenges associated with proper assessment of impacts and implications of the FNA in the agri-food sector. This study assesses preparedness for and long-term agri-food impacts of the FNA, identifies challenges in post-disaster recovery and reconstruction, and summarizes lessons learned for improving disaster risk management. Diverse research methods are incorporated ranging from policies, action, reports, and scientific, statistical, and monitoring data analysis to socio-economic, environmental, health, and expert evaluations and comparative governance assessments.

2. Preparedness and Agri-Food Impacts Assessment

The agri-food sector of Japan was not well prepared for such a big disaster and was badly affected by the FNA. Adverse long-term effects on agriculture, food industries, and food consumption were seen in a number of areas.

First, there was an enormous reduction in production and income due to radiation contamination; (mandatory/voluntary) shipment restrictions; increased costs of inputs, production, and marketing; costs of adaptation and implementation of new safety standards; and diminished market demands and prices of agri-food products. Almost 55% of farms were affected negatively by the GEJE [JFC, 2013]. In the worst-hit prefectures, 90% of farms suffered, with price declines and harmful rumours pointed out as the main reasons. Annual income loss from the FNA in Fukushima prefecture alone was estimated at 100 billion JPY [MAFF, 2013]. Damages to agriculture were particularly big in areas around the Fukushima nuclear plant, where farming and related activities were suspended or reduced. Evacuation zones affected 8% of farmers and 9% of farmlands in the Fukushima prefecture. Effective resumption of operations in the areas most affected—Fukushima, Iwate, and Miyagi prefectures—was deterred by the FNA impact, unavailable land and equipment, undecided places of settlement, and funding problems [MAFF, 2015]. The FNA was seen as a factor for not resuming farming. Similarly, 58% of food

companies were severely affected by the FNA due to cancelled orders, reduced sales and prices, and increased input supply costs; these increases were as much as 82% in the most affected regions and 94% in Fukushima prefecture [JFC, 2014]. A year after the FNA, less than 50% of pre-disaster operations were reported in 48% of the affected companies.

Second, there was radioactive contamination of farmlands, agrarian assets, and infrastructure from the FNA fallout. Radioactive caesium contaminated 30,000 km^2 or 8% of the land in Japan, 40% with radiation exceeding the allowable level [MECSST, 2011]. Heavily contaminated areas were located in eight prefectures and 101 municipalities, with farmland contamination ranging from 16 to 56,600 Bq/kg [MAFF, 2013]. There have been huge public and private costs for cleaning farmlands and agrarian assets. In Fukushima prefecture, restoration of farming is progressing slowly, while some heavily contaminated areas will require long-term remediation before farming can resume [MAFF, 2017]. The agri-food sector is a major employer in the affected regions, and after the FNA many individuals lost income opportunities. Thousands of farm livelihoods and businesses were destroyed as a result of loss of lives, injuries, displacement, and damage to property, infrastructure, and community and business relations. Much of the overall damage to farmers' livelihood and possessions, physical and mental health, environment, and lost community relations can hardly be evaluated in quantitative terms [Bachev and Ito, 2013].

Third, until the FNA there was no adequate system for agri-food radiation regulation and food safety inspection in Japan. Immediately after the FNA, the government introduced provisional regulatory limits for radionuclides in agri-food products, while in 2012 food safety standards were upgraded to the world's strictest. Widespread inspections on radiation contamination were introduced, and numerous production, shipment, and consumption restrictions on agri-food products were imposed. Regular radiation tests are now carried out for numerous agri-food products in 17 prefectures, including all rice bags in Fukushima prefecture. There have emerged many private and collective inspection systems introduced by farmers, rural associations, food processors, retailers, local authorities, consumer organizations, and independent agents; some of these employ stricter than official safety norms. A number of products from contaminated areas of 17 prefectures are subject to shipment restrains (outside Fukushima mostly covering mushrooms, wild plants, and fish). Consequently, the number of agri-food items with levels exceeding safety standards has diminished to zero in all groups but mushrooms, wild plants, fishery products, wild birds, and animal meat (Table 1). Modernization of the food safety system has taken time and been associated with enormous costs as well as public and private debate.

Fourth, after the FNA there was destruction of the supply of potable water, food, and necessities in most affected regions. Unprecedented for modern Japan, food shortages prevailed across the disaster areas and in big cities. The normal food supply to all affected people was quickly restored and important infrastructure rebuilt. There have been numerous restrictions on the production, sale, shipment, and consumption of agri-food products in affected regions, which stopped, delayed, or reduced the effective supply of a range of products. Furthermore, due to genuine or perceived health risks, many consumers stopped buying agri-food products originating from Northern Honshu. Even in cases when it was proven that the food was safe, some wholesale traders, processors, and consumers refrained from buying products from contaminated areas [MAFF, 2012]. Reputational damage was particularly important for many traditional products (rice, fruits, vegetables, mushrooms, milk, butter, beef) from affected regions, so that demand

Table 1. Ratio of inspected agricultural products exceeding official safety limit in Japan (%).

Items	FY2011	FY2016
Rice	2,2	0
Vegetables	3	0
Fruits	7,7	0
Legumes	2,3	0
Tea	8,6	0
Raw milk	0,4	0
Beef	1,3	0
Pork, poultry, eggs	0,7	0
Mushrooms, wild plants	20,2	0,7
Fishery products	17,2	0,1
Wild birds, animal meat	62,4	22,1

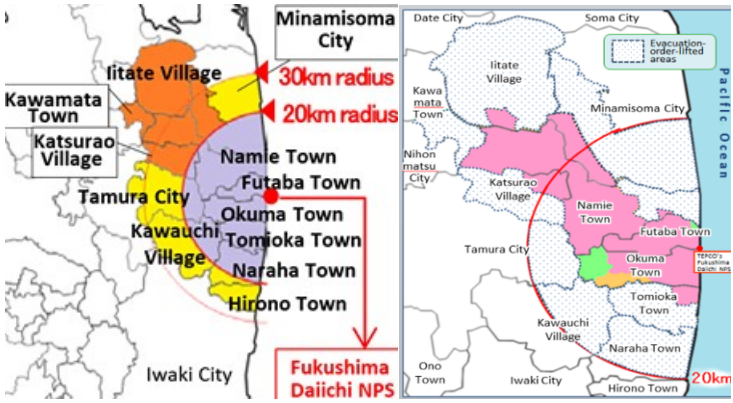
Source: Ministry of Health, Labor, Welfare.

and prices declined significantly [Koyama, 2013]. Demand for Fukushima agri-food products is recovering, but many consumers report buying rarely or not at all from the affected regions because they worry about safety [JFC, 2014]. Numerous consumers continue to disbelieve the inspection system and employ other ways to procure safe food (direct sales, contracts, origins, imports).

Fifth, the FNA adversely affected international trade, as 40 countries imposed restrictions on agri-food imports from Japan, including major importers (China, the U.S., Indonesia, Malaysia, South Korea). Many countries subsequently eased import restrictions but kept restrictions in place for Fukushima products [MAFF, 2017].

Sixth, the FNA has had positive effects on the agri-food sector in non-contaminated regions, where prices, demand, production, and sales opportunities increased. There has been a boom in technological, product, and organizational innovations, a growth of new sectors (radiation testing, decontamination, energy saving, renewable energy, nuclear safety, debris cleaning, processing and disposal, research and development, robotics, ITC, no-soil and solar sharing farming), with huge investments of leading players and the state, as well as numerous newcomers and joint ventures. All of these created new employment and income opportunities in the affected regions and in Japan overall.

According to leading experts, the major factors for long-term persistence of the negative impacts of the FNA on agriculture are consumers' unwillingness to buy, the long time required for deactivating radiation, insufficient support from the central government, low prices for produce, low confidence in official information, lack of information, the negative effect on reputation, and little preparedness on the part of public authorities [Bachev and Ito, 2018]. The most important factors for food industries are lack of information, consumers' unwillingness to buy, the long time required for deactivating radiation, little preparedness on the part of public authorities, the negative effect on reputation, insufficient support from the central government, and low confidence in official information. The most important factors for food consumption are lack of information, low confidence in official information, insufficient support from central government, and the negative effect on reputation.



Source: Fukushima Prefectural Government.

Figure 1. Evacuation zones in 2011 and 2018.

3. Major Challenges in Disaster Recovery

After the FNA, a large-scale evacuation was carried out that affected 9% of the Fukushima prefecture population. Evacuation areas and evacuees gradually decreased (Fig. 1), but "evacuation designated zones" still cover 371 km^2 (2,7% of the Fukushima prefecture territory) while 45,000 Fukushima residents (2,4% of the total) continue to live as evacuees, 75% in other prefectures [FPG, 2018].

Evacuation and reconstruction were associated with a number of challenges. There was a failure to achieve timely evacuation from certain highly contaminated areas; slow response of authorities; lack of sufficient public information in the first stages of the disaster; mistrust of public and private institutions; multiple displacements of many evacuees; divided communities and families; and poor communication between different organizations. Additionally, there was a lack of financial resources; insufficient manpower and building materials; ineffective use of public funds; discrimination toward some evacuees; emotional conflicts between evacuees (about "self-evacuation", compensation, rebuilding modes); insufficient and unequal compensation; and unequal decontamination and recovery of individual sectors (fast for the construction industry, slow for farming, services, food processing, and fisheries) and regions (much slower for Fukushima). Other challenges included workers moving away from the agri-food sector; unequal payment for work in traditional industries and the government's emergency programs; substandard labour conditions for decontamination workers; increased individual and organized crimes; a population decline (out-migration); the long time to obtain consent for reconstruction plans; difficulties of land acquisition for building cities; spikes in construction material prices; manpower shortages; lack of contractors; numerous lawsuits against TEPCO[2] and authorities; a delay in establishing the Reconstruction Agency (2012) for coordinating multiple recovery efforts; unclear government guidelines for nuclear disaster recovery; revisions in policies regarding energy and disaster prevention; lack of a detailed contamination map for all agricultural lands; and improper use of extension officers (obtaining samples while suppressing consulting, introducing technology, and education) [Bachev and Ito, 2018]. By the end of 2014, about 70% of the 58 monitored

[2] Operator of the Fukushima nuclear plant.

municipalities in seven prefectures had (almost) completed decontamination, and 12 towns had sought extensions while certain heavily contaminated areas remained untouched.

Many evacuees, especially younger ones, refuse to return even after decontamination is completed because of persistent high radiation in forests around houses and hotspots, health risks, the destruction of business and community infrastructure, and the fact that they have established a new life in other regions. Major reasons for slow progress are delayed reconstruction, the lengthy process for land decontamination, existing hotspots, restricted mobility in evacuated areas, calls for more decontamination, difficulties in safe disposal of contaminated soil and debris, population fears regarding radiation hazards, concern about the safety of the intermediate nuclear waste storage facility, lack of job opportunities, destroyed business, unrestored critical services and infrastructure, absence of a community consensus for certain projects, and uncertainty about future developments.

Insufficient decontamination of farmland and irrigation canals, decreased motivation among farmers, and local anxiety over rumours about produce are major reasons for the low resumption of farming in the evacuation zone. It has been difficult to farm efficiently (e.g., water control in paddies) since farmers were forbidden to stay permanently, there is uncertainty associated with marketing, and there is radioactive water runoff from mountains to reservoirs and paddy fields.

Food safety measures let Fukushima agri-food products become the "safest in the world", but even enormous public and private actions to increase safety and transparency have not produced a recovery of consumer trust. Demand for agri-food products from affected regions in Japan and internationally remains low due to a lack of sufficient capability in the inspection system, inappropriate restrictions (initially covering all shipments in the prefecture rather than only those localities that were contaminated), the revelation of rare incidences of contamination in regions thought to be safe, low confidence in official safety limits and inspections, lack of good communication, harmful rumours ("Fu-hyo"), and inauthentic products [Bachev and Ito, 2018].

Demand for agri-food products is recovering, but wholesale prices are lower than those at the national level. That is a consequence of the increased number of inspections, reduction of radioactive contamination, improving consumer confidence in inspection and safety, "forgetting" the contamination issue by some part of population, preference for lower prices regardless of quality by some consumers, changing marketing strategies (not promoting/labelling products as "Fukushima origin"), and increasing procurement by restaurants and processors.

There are challenges with the safety inspection system. Due to a lack of personnel, expertise, and high-precision equipment, the water, food, and soil tests are not always accurate (detecting single-digit according to a new regulation), consistent, or comprehensive. Food safety inspections are basically carried out at the distribution stage (output for shipments and exports) and do not completely cover produce sold at farmers' markets, direct sales, food exchanges, or self-consumption. While contamination has "no administrative borders", the capability for radiation safety control in Fukushima prefecture is high while in other prefectures strict tests are not carried out. Many private/collective testing equipment does not have high precision, and samples may not be properly prepared (e.g., in the case of inexperienced farmers). There have been considerable discrepancies in measurements of radiation levels in air and food done by different entities in the same location. Certain products are labelled and sold as safe despite contamination, and some tested agricultural products are further cooked or dried so that radiation reaches

higher levels before consumption. The uptake of radioactive materials with food increases during the summer season, because of the consumption of fresh vegetables and fruits, and the local population often consumes untested wild plants and home-produced food, which presents further risks.

Agri-food inspections, regulations, and countermeasures are conducted by different agencies with their own policies and not well coordinated procedures. These include the MAFF for soil contamination surveys and agri-food inspection, the MHLW for food safety standards regulations, the MECSST for monitoring air radiation, the ME for decontamination and waste disposal, the CAA for food safety training, and the RA for restoration and decontamination. There is no coordination or common procedures or standards between monitoring carried out at different levels and among different government, professional, or research organizations. Nor is there a common framework for centralizing and sharing all information and making it available to interested parties and the public.

The official "area based" system for shipment restrictions harms many farmers when permits for shipment by selected farmers would be more appropriate. Extending random sampling tests of circulating produce (at the shipment level) with management/control at the production planning stage is superior. According to many, the biggest hurdle is the lack of a clear radiation risk standard that can be universally accepted, since there are ongoing discussions among experts about safety limits, which confuses producers and consumers.

Another challenge of the inspection system is the costs for local authorities, farmers, and the food industry. The Fukushima prefectural government maintains a number of tested items, but funding is depleting, and at the same time the central government has decreased the number of items that it screens. Much of the inspection costs for cooperatives, farmers, and food processors are not compensated.

There are challenges with emerging new technologies and organizational modes. These include high building and running costs, difficulties in cultivation technique, human development, the food certification system, the need for stable marketing through integration, requirements for entrepreneurship, collective actions, the necessity for large investment, and takeover by non-agrarian entities, which are not available, well accepted, or legitimate.

Another challenge is the health risk for the population caused by radiation exposure. Thanks to timely measures (warnings, protection, evacuation, monitoring, decontamination, food inspections, treatment), radiation levels for the population have been well below the norms that would indicate damaged health [WHO, 2013]. Air dose rates around the country and within critical places in Fukushima prefecture are higher than before the disaster but comparable with major cities overseas [FPG, 2018]. Surveys in most affected regions indicate that annual radiation intake from food is less than 1% of the maximum allowed and is also decreasing [MHLW, 2018].

Official "safe" radiation exposure levels were drastically increased in 2011 from 1 mSv to 20 mSv per year. There have been debates and great concerns about the health effects from cumulative exposure above and within the official limit. These worries stem from incongruent opinions of experts, the slow process of decontamination in some areas, unresolved issues about the safe disposal of contaminated debris, deficiencies in food safety control, and continuing radiation leakages at the nuclear plant. Since the FNA, health complaints and hospitalizations have been increasing in Fukushima prefecture [Bachev and Ito, 2018]. Nevertheless, the health effects of radiation release are more psychological than physical, since many consumers and producers have lost their peace

of mind by consuming food that has radiation contamination even though it is lower than the official safety limit. The long duration of living as evacuees and lost property and employment have caused many to develop physical or mental problems, such as through stress and anxiety, and disaster-related deaths have reached several thousand. However, due to the long period of time it is becoming increasingly difficult to identify relationships between health problems/deaths and the FNA.

From October 2011 to March 2018, TEPCO paid ¥8 trillion in compensation related to the FNA, half to individuals and businesses [Brasor and Tsubuku, 2018]. Payouts have officially ended, but there are thousands of individual and collective claimants seeking or disputing compensation from TEPCO or the authorities (courts and others). The estimated compensation amount grows each time the government issues new guidelines. A number of false claims and swindling compensation funds for millions of yens have also been reported. Progress in making compensation payments has been slow and uneven due to delays in TEPCO's review process; a large amount of paperwork; lengthy negotiation; partial payments; disputing the origin of damages; denying claims when production or distribution is restrained voluntarily; uncompensated damage to farmland, property, and the discontinuation of business; disagreements over the closing date for compensation; insufficient amounts to restart farming/sustain consumption; uncompensated costs to organizations for inspection, administration, and radiation map preparation; unclear specifications for damages in the guidelines; negotiation asymmetry for farmers marketing through cooperatives; high lawyers' costs; uncompensated safety test costs for farmers and consumer associations; lack of clarity on how certain claims can be compensated; cash-flow difficulties and interest payments; and uniform compensation "per ares" while there are differences in products, value added, and farming method (organic vs. conventional).

There is uncertainty about the full costs related to the FNA since their level expands constantly. Initial government estimates (2014) were that it would take ¥11,16 trillion and 40 years to clean up the Fukushima site, including 2,5 trillion for decontamination, 1,1 trillion for interim storage facilities, 2 trillion for reactor decommissioning, and 5 trillion for compensation. In 2018, compensation payments are more than ¥8 trillion while the budget for decontamination is ¥2.9 trillion [ME, 2018]. The process of decommissioning nuclear reactors is at the beginning stage and includes many challenges: lack of experience, available technologies, uncertainties and risks, multiple failures, public concerns, and lack of a disposal site.

For a long period during the decontamination process, soil, vegetation, mud, and other radioactive waste amounting to 16–22 mil.m^3 is being stored in thousands of temporary storage sites across Fukushima and 12 other prefectures [ME, 2018]. "Designated waste" containing radioactive substances measuring more than 8,000 Bq/kg is 143,689 tons. New temporary (30-year) storage facilities for radioactive waste near the nuclear plant has been operational since 2017; 513 m^3 have been transported there. A site for final disposal of radioactive waste outside of Fukushima prefecture has been chosen in spite of the opposition of local residents (radiation fears, environmental threat, risk for agro-product marketing). After the FNA, all 54 nuclear reactors were shut down for stress tests and compliance with the new (2013) safety standards, the world's strictest. Until 2018, only five nuclear plants (nine reactors) had resumed operations. Experts have found official estimates to be over-optimistic, predicting that FNA costs will increase up to the national annual tax (¥43 trillion) [Okuyama, 2014].

The government has reported that release of radioactive materials following the FNA remains Japan's biggest environmental problem. According to some experts, large-

scale decontamination creates new eco-problems: huge amounts of radioactive waste, removal of top soil, damage to wildlife habitat and soil fertility, increased erosion on hillsides and forests, and intrusion by people and machinery into every ecosystem. All these difficulties and uncertainties make it difficult to access the full socio-economic and environmental impact of the FNA, and require long-term monitoring and actions.

4. Lessons Learned from Japanese Experiences

Major lessons from the Japanese experience with the FNA in terms of the agri-food sector—readiness, impacts, and recovery—include the following:

- The triple March 2011 disaster was a rare but high-impact event, which came as a surprise even for a country with frequent natural disasters and a well-developed disaster risk management system. It is necessary to prepare for the unexpected and to design, build, and test a multi-hazard disaster risk management system for specific conditions of each country, region, and sector. Appropriate measures and sufficient resources (funding, personnel, stockpiles, shelters, transport means) have to be planned for effective prevention, early warning, mitigation, response, and post-disaster relief and recovery. In addition to state resources it is important to mobilize huge private, community, NGO, and international capabilities, expertise, and means, since a public–private partnership is necessary to identify and designate all resources in cases of big destruction and evacuation.
- Risk assessment should include diverse hazards (health, dislocation, economic, behavioural, ecological) and complementary chains (food, supplies, natural, biological), spin-offs, and multilateral effects of a likely disaster, either natural or manmade. Modern methods and technologies are to be widely employed (social networks, computer simulations, satellite imaging) for effective communication, preparation of disaster maps, assessment of likely impacts, planning evacuation routes, relief needs, and recovery measures, as well as securing debris and waste management. It is crucial to involve multidisciplinary and multi-stakeholders' teams in all stages of risk management to guarantee a holistic approach, full information and transparency, adequate risk assessment, preferences and capabilities, and maximum efficiency.
- A risk management system must be discussed with all stakeholders, and measures must be taken to educate/train individuals, organizations, and communities for complex disasters and all contingencies. Individual responsibilities are to be well specified, and effective mechanisms for coordination of actions of authorities, organizations, and groups at different levels must be put in place and tested to ensure efficiency (speed, lack of duplication, gaps) during an emergency. Individual and small-scale operators dominate in the agri-food sector of most countries, and their proper information, training, and involvement is critical. Involvement should embrace diverse agri-food and rural organizations, consumers, and populations of each age group which have no disaster management culture, knowledge, training, or plans—particularly for large disasters.
- It is necessary to modernize the formal institutional environment (property rights, regulations, safety standards, norms) according to the needs of contemporary disaster risk management. Particular attention is to be put on updating

agri-food safety, labour, health, and animal welfare standards, and ensuring adequate mechanisms, qualified agents, and technical instruments for effective implementation. The agri-food inspection system should be improved by creating uniform inspection manuals and standards, enhancing coordination and avoiding duplication, establishing inspection across prefectural borders, and having the management system extend random sampling tests of marketed produce with management at the production planning stage.

- It is important to set up mechanisms to improve the efficiency of public resource allocation, avoid mismanagement and misuse of resources, reduce individual agents' costs for complying with regulations and using public relief, and support the court system for and dispute resolution. This would achieve the efficient allocation of limited social resources according to agents' needs and preferences, intensify and speed up transactions, improve enforcement (rights, laws, standards) and conflict resolution, decrease corruption, and accelerate recovery and reconstruction. It is obligatory to involve all stakeholders in decision making and control, and to increase transparency at all levels and stages of disaster planning, management, and reconstruction. In case of evacuation, it is essential to secure proper (police, voluntary group) protection of private and public property from thefts and wild animal invasion in disaster zones.
- Different agents and elements of the agri-food chain are affected in different ways from a disaster and have dissimilar recovery and adaptation capability. Most farming assets (multiannual crops, irrigation facilities, buildings, brands, biodiversity, landscape) are interlinked with land, and if land is damaged a rapid recovery in terms of rebuilding, relocation, and alternative supplies is very costly or even impossible. Smaller-scale and highly specialized enterprises, small-member communities and organizations, and visitors and tourists are more vulnerable and less able to protect themselves, bear the consequences, and recover. All of this requires differential public support (intervention, compensation, funding, assistance) to various types of agents in order to provide emergency relief, accelerate recovery, and diminish the negative consequences.
- There is a strong regional specificity and interdependency for agrarian, food, and rural assets. If a part of assets/products is damaged/affected due to destruction of critical transportation, communication, distribution, electricity, and water supply infrastructure or to nuclear, chemical, or pathogen contamination, all agents in the respective region are affected—including undamaged lands, livestock, produce, and services. To minimize damages, it is important to properly identify and locate risk and take preventive measures, rapidly recover critical infrastructure, strictly enforce the quality (safety, authenticity, origin) of products, and adequately communicate them to producers, processors, distributors, consumers, and the international community.
- Establishing an accessible cooperative, quasi-public, or public insurance system for agriculture (crops, livestock, machinery, buildings, life and health), including assurance against big disasters, is very important for rapid recovery of affected agents and sectors. Modernization of an outdated and often informal registration and valorization system for land, material, and biological and intellectual property is important for effective post-disaster compensation, recovery, and reconstruction. That is particularly true for numerous subsistent and "semi-market" holdings that dominate the agro-food sector worldwide, which usually

suffer significantly from disasters but get no market valuation, insurance, and/or public support.

- Specific responses to the 2011 disasters highlighted the comparative advantages of traditional communities and non-governmental organizations, and less efficient but more resilient structures (small operators and partnerships) and sectors (one-season crops, poultry, pigs, processing). An important role was proven following the FNA for small-scale farms and food organizations, informal networks, and leadership in terms of rapidly restoring the agri-food supply, securing food safety and transparency, effectively recovering and reconstructing, achieving technological and organizational innovations, and implementing networked or decentralized actions. These governing modes have to be included in the disaster management system, with relevant actors properly trained and appropriate responsibilities assigned.
- Good management of information and communication is extremely important during emergencies and in recovery and post-disaster reconstruction. The FNA proved that any delay, partial release, or controversy regarding official information hampers effective (re)actions of agents, and it adversely affects public trust and consumer behaviour. Before, during, and after a disaster all available information (risk, monitoring, measured, projected) from all reliable sources is to be immediately publicized, in a form that is understandable by everyone, through all possible means, including official and community channels, mobile phones, and social media. It is essential to publish alternative (independent, private, scientific, international) information, including in foreign languages, which builds public trust and increases confidence. In Japan it has been difficult to find all available information related to the FNA (such as updates, diverse aspects, unified measurements, time series, and alternative sources) in a timely and systematized way, making many foreigners and local residents sceptical about accuracy.
- A large disaster provides an extraordinary opportunity to discuss, introduce, and implement fundamental changes in agricultural, economic, regional, energy, and disaster management policies. It also provides an opportunity to improve disaster management and food security, modernize regulation and standards, relocate farms and houses, consolidate lands and operations, upgrade infrastructure, restructure production and farming organizations, introduce technological and business innovation, and improve the natural environment. All opportunities should be effectively used by central and local authorities through policies, programs, measures, and adequate support for innovative private and collective initiatives.
- The importance of international cooperation in all areas has been proven in responses to and recovery from the FNA through sharing information, knowledge, expertise, know-how, and specialized equipment. It is particularly crucial to share the advanced Japanese experience internationally through media, visits, studies, and conferences, and to turn Fukushima into a disaster risk management hub for other regions and countries. Positive Japanese experiences should be adapted to specific institutional, cultural, natural environment, and risk structures of each community, subsector, region, and country.
- It is essential to learn from past experiences and make sure that lessons learned are not forgotten. The impacts and factors of disasters, disaster management,

and post-disaster reconstruction should be continuously studied, and knowledge should be transferred to the next generation. It is critical to share good and bad experiences with disaster prevention, management, and recovery with other regions and countries.

5. Conclusion

Eight years after the FNA, there are still a number of social, economic, health, food safety, technological, and environmental challenges during recovery and reconstruction in the region and elsewhere. Agriculture, the food industry, and food consumption are among the areas that are worst hit by disasters. The agri-food sector of Fukushima prefecture was severely affected, and there were significant adverse consequences to other regions and food chains nationwide. Many of these negative effects can hardly be expressed in quantitative terms.

Post-disaster recovery and reconstruction gives opportunities to learn from the experience. There are opportunities to revamp policies and institutions around the agri-food, energy, and security sectors; and to improve disaster prevention and management, food safety information and inspection, technological and product innovation, jobs creation and investment, farmlands consolidation and enhancement, infrastructural amelioration, and organizational restructuring.

This study is just a new attempt to assess disaster management readiness, describe the impact of the FNA, and summarize lessons for agri-food chains. Research is incomplete due to the still short period of time after the disaster, as well as to insufficient and controversial data, and to difficulties in adequately assessing the longer-term implications. Thus more in-depth interdisciplinary studies will be necessary to fully evaluate the agri-food impacts and improve disaster risk management.

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