

IMPLICATIONS OF FUKUSHIMA NUCLEAR DISASTER FOR JAPANESE AGRI-FOOD CHAINS

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Abstract

There are few English publications on various impacts of Fukushima nuclear disaster on agri-food sector in Japan. This paper fills the gap and presents results of a study on implications of Fukushima nuclear disaster for Japanese agri-food chains. Firstly, immediate and short-term radiation effects, and effects on nearby population, safety regulation and inspection system, markets and consumer's behavior, agrarian and food products, health, and economic impacts on farming and agri-businesses, are assessed. Next, overall shorter and longer-term impacts on agriculture, food industries, and consumers in Fukushima region, neighboring regions, and other parts of Japan are estimated.

Key words: *Fukushima nuclear disaster, impacts; agriculture, food chains, Japan*

1. Introduction

On March 11, 2011 Great East Japan Earthquake occurred which triggered powerful tsunami. It caused a nuclear accident in one of the world's biggest nuclear power stations - Fukushima Nuclear Powerplant. Radioactive contamination has spread through air, rains, dust, water circulations, wildlife, garbage disposals, transportation, and affected soils, waters, plants, animals, infrastructure, supply and food chains in immense areas.

There are numerous publications on impacts of Fukushima nuclear disaster on agricultural lands, farm crops and livestock, agricultural and food products, farmers, local communities, consumers behavior, agri-food trade etc. (Fujita et al., 2012; Johnson, 2011; MAFF, 2012; Koyama, 2012, 2013; Murayama, 2012; Nakanishi & Tanoi, 2013; Oka, 2012; Ujii, 2012; Yasunaria et al., 2011; Watanabe, 2011). Due to scale of contamination and affected agents, impact's multiplicities and evolution, spillovers, long time horizon, lack of "full" information and models of analysis, overall impactations of disaster on Japanese agri-food sector is not completely evaluated (Koyama, 2013).

This paper assesses diverse impacts of Fukushima nuclear disaster on Japanese agriculture and food chains. Wide range of official, research, media, professional organizations, and Tokyo Electric Power Company (TEPCO, 2013) information is used. In-depth interviews and assessments of experts, representatives of government, farmers, food industry, and consumers were carried in June 2013.

2. Immediate and Shorter Terms Effects

2.1. Radiation Effect

According to data 538,100 TBq of iodine-131, caesium-134 and caesium-137 was released, including 520,000 TBq released into atmosphere (March 12-31) and 18,100 TBq into ocean (March 26-September 30) (TEPCO, 2013).

In November 2011, Ministry of Science and Technology reported that long-lived radioactive cesium had contaminated 30,000 sq km of land surface while 11,700 sq km was found to have radiation levels that exceeded allowable exposure rate (1 mSv/per-year). Latest data show that environmental radioactivity in most prefectures is higher than before accident (NRA, 2013). In Fukushima prefecture radiation varies according to location and it is much higher than before disaster (Table 1).

Table 1. Environmental radioactivity in Fukushima prefecture, June 11, 2013 ($\mu\text{Sv/h}$)

	Ken-poku, Fukushima City	Ken-chu, Koriyama City	Ken-nan, Shirakawa City	Aizu, Aizu Wakamatsu City	Minami Aizu, Minami Aizu Town	Soso, Minami Soma City	Iwaki, Iwaki City Taira
Direction and distance from nuclear power plant	North west, about 63km	West, about 58km	South west, about 81km	West, about 98km	West south West, about 115km	North, about 24km	South southwest, about 43km
Normal value*	0.04	0.04-0.06	0.04-0.05	0.04-0.05	0.02-0.04	0.05	0.05-0.06
June 11, 2013	0.35	0.18	0.13	0.07	0.05	0.15	0.09

Source: http://www.worldvillage.org/houshano_deta/houshano_e.pdf

*radioactivity levels surveyed in 2010

Radioactive contamination of agricultural lands has not been fully investigated (Koyama, 2013). It differs widely for individual fields – e.g. samples from rice-paddies in Fukushima ranged from 400 Bq/kg to 4,000 Bq/kg (Koyama, 2012). Decontamination process is slow as 8% of lands outside evaluation zones were decontaminated by end-2012, and 62% of affected farmland is not restored [NHK World, 2013a,c]. There are many hot-spots with excessive contamination.

2.2. Effects on Population

Authorities have been implementing 20 km (800 sq km) exclusion zone and other restricted areas around nuclear plant. Affected area is divided into following categories: Restricted area (20 km radius from plant); Areas to which evacuation orders are ready to be lifted (entry permitted, overnight stay not); Areas in which residents are not permitted to live where annual integral dose of radiation is expected to be 20 mSv or more (entry is not recommended, allowed during daytime); No entry areas where annual integral dose of radiation is expected to be 20 mSv or more within five years and current integral dose of radiation per year is 50 mSv or more; 5) Specific spots recommended for evacuation.

Table 2. Number of farms, farmland, livestock in evacuated area

Indicators	Evacuation area:				
	Total	% in Fukushima total	In hazard area	In emergency evacuation preparation zone	In planned evacuation area
1. Number farms	7654	10.68	4123	2272	1259
Total farmland (a)	1,534,398	12.63	788,971	414,321	331,106
- Rice-paddy	1,124,843	12.42	637,207	326,749	160,887
% of rice-paddy	73.31				
-Upland	392,963	15.68	138,064	85,365	169,534
% of upland	25.61				
-Permanent crops	16,592	2.83	13,700	2,207	685
% of permanent crops	1.08				
2. Number farms above 30a* or 500000 yen income	7454	10.57	4022	2232	1200
Total farmland (a)	1,390,223	12.01	731,921	405,020	253,282
-Rice-paddy	1,053,231	12.01	591,859	320,478	140,894
% of rice-paddy	75.76				
-Upland	322,493	14.39	128,105	82,665	1,877
% of upland	23.20				
-Permanent crops	14,499	2.54	11,957	1,877	665
% of permanent crops	1.04				
3. Number farm population	10,616	9.74	5,477	3,172	1,967
4. Farms with milk cows	127	16.89	52	34	41
Number cows	2,434	13.96	1,167	705	562
5. Farms with beef cattle	814	22.12	282	311	221
Number beef cattle	9,097	17.24	3,364	2,955	2,778
6. Farms with pigs	9	13.85	7	0	2
Number pigs	4,808	13.41	4,416	0	392
7. Farms with hens	18	10.17	9	4	5
Number hens	92,712	24.04	90,872	1,660	180
8. Farms with boilers	10	17.86	4	1	5
Number boilers	995,743	29.21	478,000	12,000	505,743

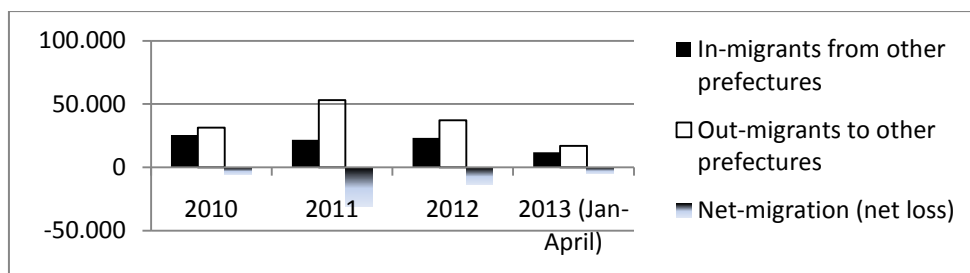
*traditional measure for land area in Japan = 0.01ha

Source: Fukushima Prefectural Government

Two years on 154,148 residents are still displaced, including 57,135 outside prefecture (JANIC, 2013). Statistics shows that population of Fukushima prefecture has been decreasing due to out-migration (Figure 1).

Some assessment range total economic loss in evacuation zone from 250-500 billion USD (NewsonJapan.com; Gundersen&Caldicott). Cesium-137 has half-life of 30 years it will maintain “ownership” of exclusion zones for many years.

Farms and food-chain companies’ property and related infrastructure were contaminated, lost value and abandoned while livelihood and businesses of many destructed. Data show that negative impact on farm households is significant (Table 2).



Source: Statistics Japan, Ministry of Internal Affairs and Communications

Figure 1. Number of in/out-migrants in Fukushima prefecture

Many refuse returning back and start revitalization because of health risk, destructed business and community infrastructure. According to prefectural government 50% of farms did not return to their land and it is not clear when they will.

Overall number of affected farms, agri-businesses and damages is unknown. Total number of farms in Tohoku, Kanto and Chūbu greatly impacted by accident is 241,761, 276,193 and 370,499 accordingly (MAFF, 2012).

2.3. Contamination of Agri-food Products

Radioactive contamination of crops, livestock and agri-food products occurred as result of direct exposure, fallouts and distributed by wind and rains, crop and livestock uptakes from soils, waters and feeds, diffusion from affected inputs, buildings and equipments, dissemination through transportation and wildlife.

Inspections multiplied showing no radioactive cesium above safety limits in milk, wheat, burley, chicken, and egg, while in other agri-food products (but mushrooms and wild plants) insignificant tests above safety limit (Table 3, 4).

Table 3. Results of inspections on radioactivity levels in agricultural products in Japan

Category	March, 2011 - March 31, 2012			April 1, 2012- January 31, 2013	
	Number of samples	Above provisional limit	Above the new limit	Number of samples	Above the maximum limit
Rice	3,217	1	9	10.2 million	71
Wheat and burley	566	1	27	1,816	0
Vegetables	11,998	139	385	16,440	5
Fruits	2,724	28	321	4,299	13
Pulse	698	0	16	4,324	21
Mushrooms and wild edible plants	4,193	323	2,070	5,882	599
Tea/Tea infusion*	2,232	192	1,562	825*	13*
Raw milk	1,914	1	7	2,054	0
Beef	92,683	157	1092	130,090	2
Pork	529	0	6	716	1
Chicken	225	0	0	353	0
Egg	419	0	0	425	0

Source: www.maff.go.jp/j/kanbo/joho/saigai/s_chosa/other/result_agri_2012.html

Table 4. Results of inspections on radioactivity levels in food products in Fukushima prefecture

Items	March, 2011 - March 31, 2012		April 1, 2012- March 31, 2013	
	Number of samples	Above provisional limit	Number of samples	Above the maximum limit
Vegetables and fruits	5,976	145	7,264	7
Milk	651	15	441	0
Meat	5,001	0	6,310	0
Eggs	221	0	144	0
Mushrooms and wild plants	956	127	1,090	90
Fish	3,330	227	6,037	879
Forage for livestock	773	162	1,664	48
Brown rice	1,724	0	35,238	71
Cereals without rice	607	3	2,169	10
Others	51	2	68	1
Total	19,290	681	60,425	1,106

Source: <http://www4.pref.fukushima.jp/nougyou-centre/>

2.4. Effects on Food Safety Regulation and Inspection System

Before accident there was no adequate system for agri-food radiation regulation and inspection to deal with such disaster. After that numerous food safety measures were taken by government. Widespread inspections on radiation contamination were introduced and shipment and consumption restrictions on agri-food products imposed, some of them still in place¹.

On 17 March 2011, Ministry of Health introduced regulatory limits for agri-food products radionuclides. Since April 1, 2012 new higher than international standards limits on radioactive elements in food items are enforced (Table 5).

Table 5. Limits on radioactive elements in foodstuff in Japan (Bq/kg)

Food item	Old norm	New norm
Rice, meat, vegetables, fish	500	100
Milk, milk-powder, infant-food	200	50
Drinking water	200	10

Source: Ministry of Health, Labor and Welfare

All rice bags produced in Fukushima prefecture are checked by Agricultural Cooperative inspection. There have emerged many inspections systems introduced by farmers and rural associations, food processors, retailers, local authorities, consumer organisations, independent agents. Voluntary restrictions on sale have been also introduced. Some producers, processors and retailers applied lower than official radiation norms.

Due to lack of personnel, expertise, high-precision equipment, water, food and soil tests are not always accurate, consistent and comprehensive. Food safety inspections are basically

¹ products subject to restrictions http://www.maff.go.jp/e/quake/press_110312-1.html

carried at distribution stage, and do not cover produce for farmers markets, direct sells, food exchanges and self-consumption². Capability for radiation safety control in Fukushima is significantly higher than in other affected regions, while contamination has “no administrative borders”.

Many privately and collectively employed testing equipments are not with high precision, and/or samples are properly prepared for analysis. Some sold products are labeled as “Not detected” despite existing contamination. Agricultural products are further cooked or dried reaching higher levels of radiation at consumption stage. Radioactive materials uptake with food by local residents increases during summer when most fresh vegetables and fruits are consumed. There are untested wild plants which are widely consumed. There are discrepancies in measurements of radiation in air and food done by different organisations.

Inspections and regulations are conducted in vertically segmented administration with “own” policies and not-well-coordinated procedures. Soil surveys and inspection of agricultural produce is conducted by MAFF, monitoring of air radiation by MEXT, regulations on value determination of food products by MHLW, training on food safety by Consumer Affairs Agency. There are not common procedures/standards nor effective coordination between monitoring carried at different levels and organizations. Neither there is common framework for centralizing and sharing related information, and making it immediately available. There is on-going discussions among experts about “safety limits” which additionally confuses producers and consumers.

2.5. Effects on Markets and Consumer Behavior

Due to genuine or perceived health risk many consumers stop buying agri-food products from affected regions. Even when it was proven that food is safe some wholesale traders, processors and consumers restrained (Futahira, 2013; Koyama, 2012, 2013; Watanabe, 2011). That has been result of insufficient capabilities in inspection system, inappropriate restrictions (initially covering all shipments rather than contaminated localities), revealed incidences of contamination in safe origins, low confidence in “safety” limits and inspections, lack of good communication, harmful rumors (“Fu-hyo”), and not-authentic character of traded products. Demand for many traditional farm produce from affected regions (rice, fruits, vegetables, mushrooms, milk, butter, beef) significantly declined while prices considerably decreased.

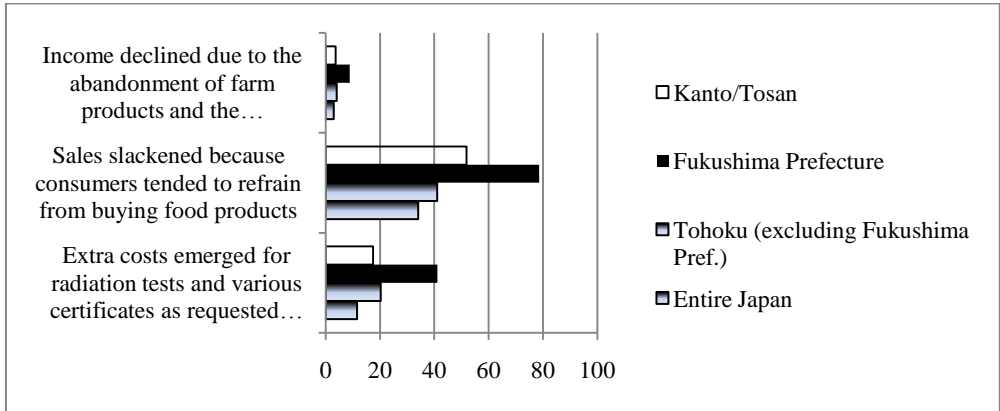
Since autumn 2011 radiation tests in all beef and package of rice is carried in Fukushima prefecture. Despite that many consumers continue to avoid Fukushima products (Takeuchi&Fujioka, 2013]. In end March 2013 rice sales from Fukushima is almost half of what it was before disaster while rice prices considerably lower..

Half of surveyed consumers in Tokyo and Osaka said they would not buy Fukushima and Ibaraki products with “contamination less than official criteria”, and another 30% said they would not if products were “not contaminated at all” (Ujii, 2012, 2013]. Recent survey shows that consumers maintain high risk conscious but “origin of product” factor is playing less important role. Residents of Fukushima also avoid local products and this is particularly true for some segment of population (family with children) and products (mushrooms and seafood).

More than a third of surveyed Japanese farmers (Figure 2) and almost of 38% of food industry personnel (Figure 3) indicate that “Sales slackened because consumers tended to refrain from buying food products”. Figures are much higher for most affected regions. Substantial number of food industry companies point out that they “switched from

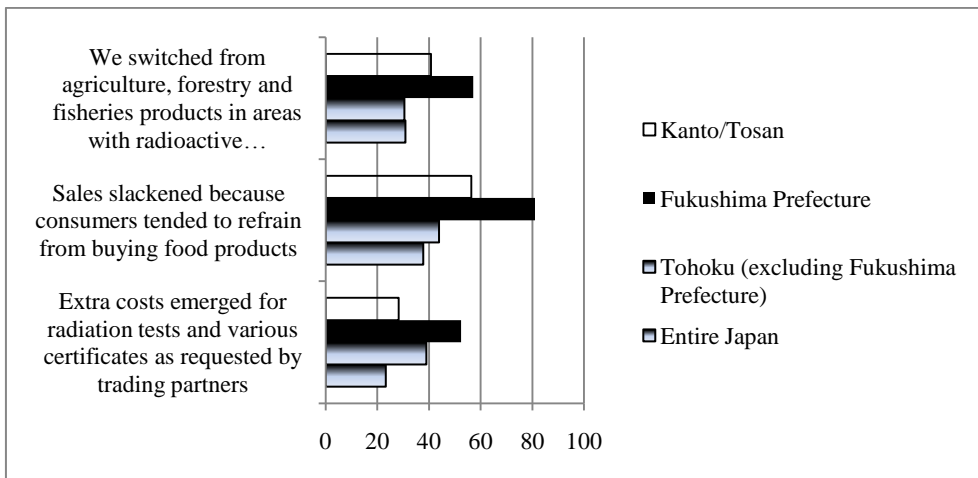
² recently municipalities strengthened inspections for self-consumed products.

agriculture, forestry and fisheries products in areas with radioactive contamination fears to those in other areas for our purchasing” and that amounts for more than 57% in Fukushima (Figure 3).



Source: MAFF, Survey conducted in January-February 2012

Figure 2. Effects of TEPCO nuclear plant accident on farmers (% , multiple answers)

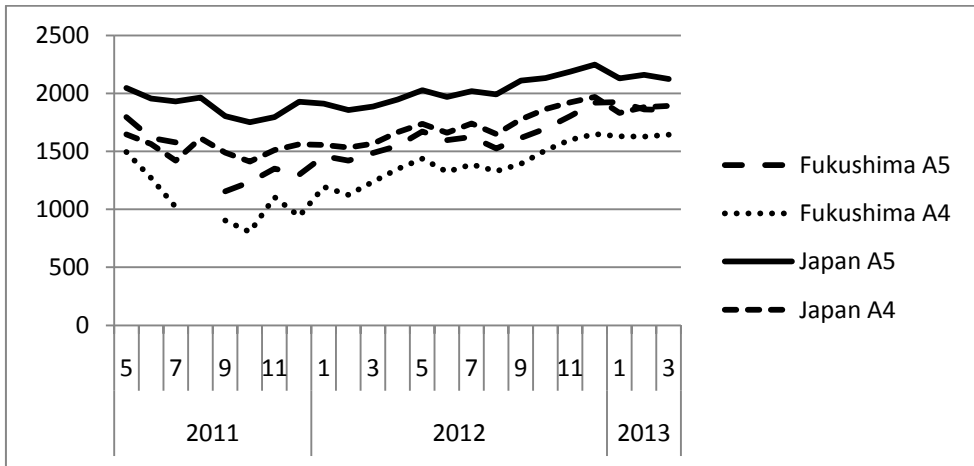


Source: MAFF, Survey conducted in January-February 2012

Figure 3. Effects of TEPCO nuclear plant accident on food industry (% , multiple answers)

Prices of major farm produces from affected regions significantly declined while prices from other regions went up. Effect on price level can be demonstrated by dynamics of beef cattle. There was considerable decline in wholesale prices of beef cattle in Fukushima prefecture and in Japan after accident (Figure 4). Prices in country have been recovered and there has been gradual recovery in Fukushima but prices are still 12-13% lower. Similar

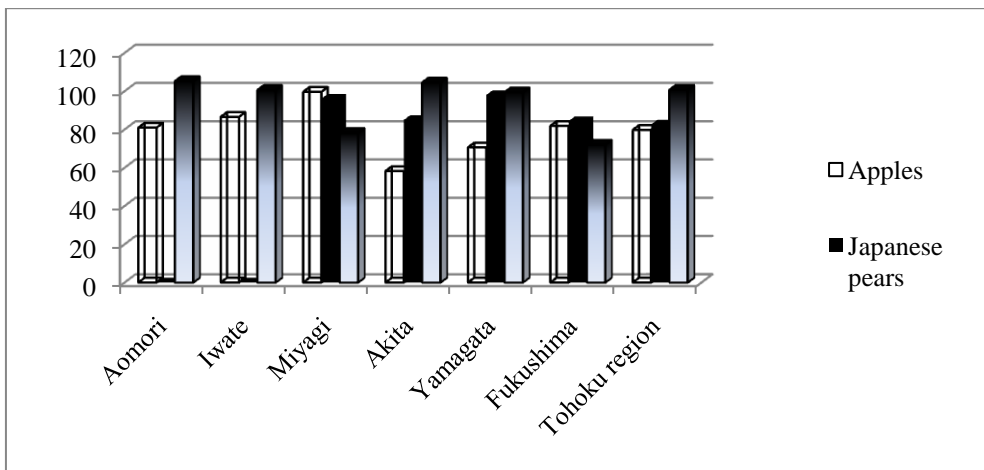
trends have been observed for other major products like peaches and cucumbers (Nakashima, 2013).



Source : Central JA Union for Fukushima Prefecture

Figure 4. Evolution of wholesale prices for beef cattle (yen/kg)

Prices of fruits in Fukushima prefecture (mostly bought for gifts) largely recovered since consumers choice of these products isnot determined by price but “origin of product” factor. There has been considerable decrease in shipments of major farms products from affected regions – in 2011 there was big decline in apples, Japanese pears and radish from Fukushima and Tohoku region (Figure 5).



Source: Statistical yearbook of MAFF

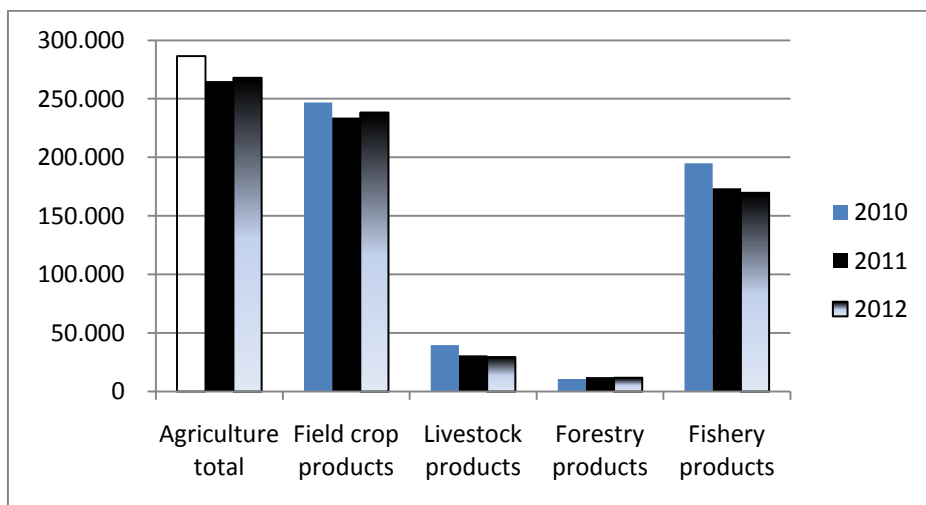
Figure 5. Dynamics of shipments of farm products from Tohoku region, 2011 comparing to 2010 (%)

Consumers in affected regions and Japan have seen their direct procurement (prices) and transaction (information, search, assurance) costs for supply of safe agri-food increased. Uijie studies proves that way to minimize transaction costs from many costumers is using “origin of product” selective governance

Recent data shows that demands for Northern Honshu agricultural products (rice, beef, vegetables) recovers fast while farm-gate and wholesale prices in most affected regions (Fukushima, Ibaraki) are still lower than in other part of Japan. Factors responsible for that are: improving consumer confidence on inspection and safety, “forgetting” contamination issue by part of population, preferences to lower prices regardless quality by some segment of consumers, changing marketing strategies of processors and smaller shops (not promoting/labeling anymore “Fukushima origin”), increasing procurement by restaurants and processors of safe and cheap produces from region. Despite negative impact on local producers in affected region some actors in food chain (restaurants, food stores, middleman) profit enormously getting higher margin.

Data on 2011 person’s daily food intake isnot available and we could only guess weather thare is changes in consumption pattern.

Around 40 countries imposed restrictions on agri-food imports from Japan after accident, including major importer. By 2012 most of them eased import restrictions from affected prefectures but kept restrictions for Fukushima. Due to import restrictions value of Japan’s farm and livestock product exports declined - in April-December 2011 plunged by 40.9 billion yen (11%) (MAFF, 2012). There is decline in post 2010 agricultural and fishery export (Figure 6), while import of agricultural, forestry and fishery products increased (MAFF, 2012).



Source: Statistical yearbook of MAFF

Figure 6. Dynamics of agricultural, forestry and fishery export of Japan (million yen)

2.6. Economic Effects on Agri-Food Chains

Scale and directions of negative effects on Japanese farms, agri-businesses and final consumers have been huge. Recent estimates on public costs for decontamination of lands

“up to reasonable level of radiation” in Fukushima prefecture are 50 billions USD, or 4 times higher than initial expectations (NHK World, 2013a).

There have been enormous costs of individuals, households, private organizations, collectives and communities which are difficult to assess. Some economic impacts could hardly be measured in quantitative (monetary) terms as: lost livelihood and accumulated with many generations capital (community relations, permanent crops, livestock herds, established brands, networks), degraded natural resources (farmlands, waters, crop and livestock varieties, biodiversity, landscape), labor health implications (reduced productivity, increased healthcare costs) etc.

Immediate and shorter-term effects on farms and agri-business were in following directions (Figure 7):

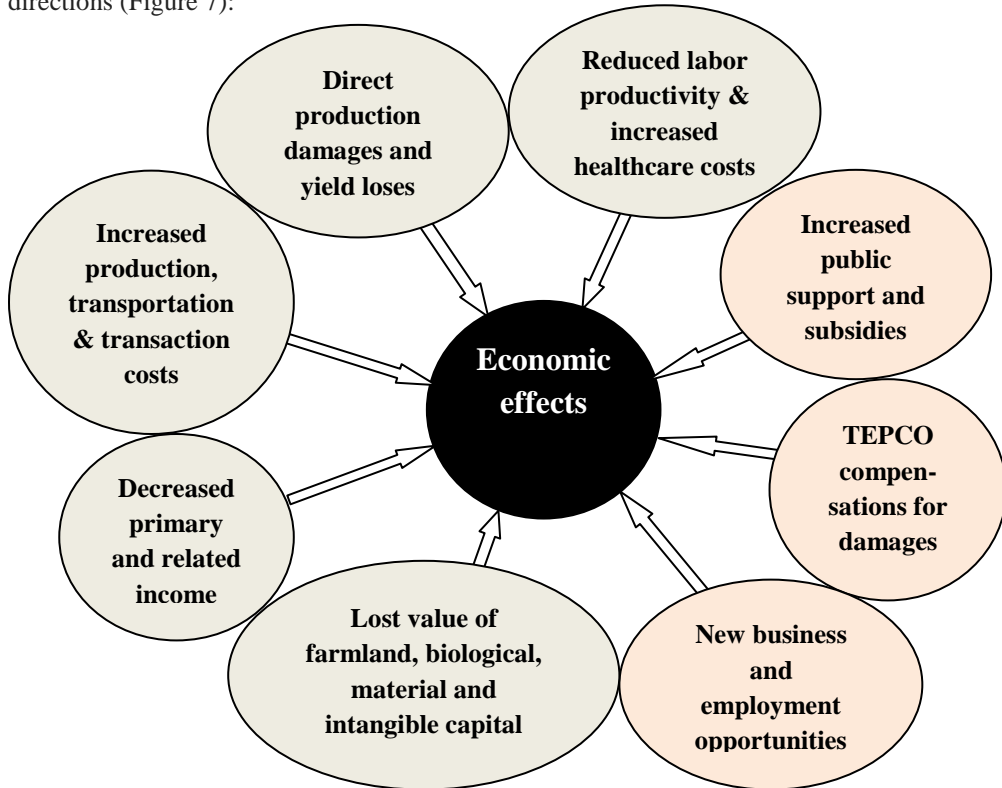


Figure 7. Economic effects from Fukushima nuclear disaster on farms and agri-business

1. Direct production damages on crops and livestock products due to radiation contamination and bans. Large amount of yields (milk, vegetables, fruits) was lost since it was not safe to consume or process.
2. Decreased income due to production and/or shipment restrictions and low market demands. In April 2011, government restricted planting of rice and other crops in soil exceeding 5,000 Bq/kg of cesium. There was ban or delays of shipment of beef and other major produces. Consequent of voluntary restrictions, declined consumer demands,

reduction in number of local population and tourists, and “harmful humors” many farmers and business lost significant markets and income.

Before disaster Fukushima prefecture was known as “Tokyo's vegetable basket” and it was Japan’s second largest producer of peaches, third largest producer of Japanese pears, fourth largest producers of rice, fifth largest producer of apples, twelfth largest producer of grapes etc. Same was true for Ibaraki prefecture famous with highest production of melon, lotus roots, and blades like potherb mustard, pakchoi and honewort, second highest production of rice in country. Great majority of surveyed by Fukushima Food Industry Organization companies report lower income due to decline in sales after accident. Similarly, popular agri and rural tourism and other related businesses in affected areas were badly damaged.

Agri-business was major employers for family and non-family labor in many of affected regions. After accident great number of workers lost temporary or permanently employment (income) opportunities.

3. Increased production, transportation and transaction costs in agri-food chain. Many farmers and business have seen their costs associated with post-disaster recovery, destructed inputs supply, shifting to new suppliers from other regions/countries, decontamination of crops, farmlands, material and biological assets etc. increased. Number of technologies were recommended to decontaminate yield, fruit trees and soils. These measures have been accompanied with additional production and learning costs to farmers. There have been additional costs to protect labor and clean equipments used in contaminated environment, adapt new structure of products and technologies with reduced radiation absorption, partial and complete dislocate business etc.

Many livestock farmers had to buy forage from other locations to feed animals occurring significant costs. In May, 2011 about 20,000 livestock farmers in seven prefectures were asked to refrain from grazing cattle affecting 700,000 heads and costing 50 billion yen in forage (Yomiuri Shimbun, 2011). Most surveyed by the FFIO companies report lower income due to higher costs of alternative supply of ingredients from other prefectures.

There have been considerable transaction costs for: adaptation to new more strict official safety standards, and voluntary restrictions imposed by professional organizations and authorities; multiple safety tests and certifications of inputs and output; “additional” relations with public authorities, TEPCO, farmers organizations and other (research) institutions; inputs supply, product promotion and marketing; providing guarantees; communications with counterparts and consumers; alternative supply trough import from other regions and/or countries.

Radiation levels in all baggage of rice and beef have been checked by JA Fukushima since autumn 2012 and September 2011. There have been significant individual and collective costs associated with negotiation, application, disputing etc. of claims for damages from TEPCO. Most surveyed by FFIO companies report “additional costs and efforts” to deal with food safety risks and harmful humors: performing radiation checks on new acquired equipment, outside tests, consumers and clients information, “hard working”, products safety promotions through meetings, website, labeling.

There has been huge increase in “public relation” costs of prefectural and local governments aimed at improving the damaged image of Fukushima products.

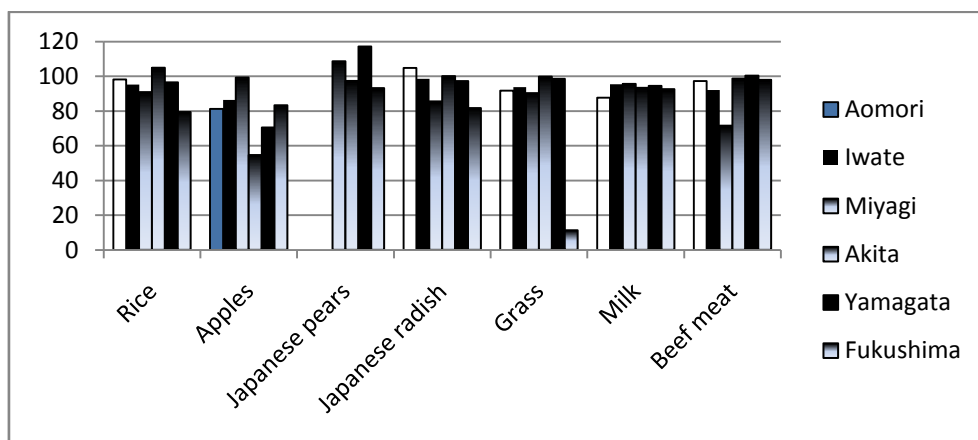
4. Subsequent of contamination, dislocation, institutional restrictions, and/or reduced markets for regional products, many farmers and agri-businesses have lost significant portion of value of farmlands, livestock, orchards, material assets, and intangibles (established relations, reputation, brands, labels, product origins) – e.g. popular Fukushima brand products such as Idate beef and Anpo gaki were destructed.

5. There has been unspecified effect on reduction of labor productivity, increased healthcare and recreation costs due to accident.

Economic effects have been unlike for different agents and various regions. Greatest negative impacts on costs and sales have been experienced by farms and businesses in Fukushima and neighboring regions. More than 41% of farmers and 52% of food industries in Fukushima prefecture report “extra costs emerged for radiation tests and various certificates as requested by trading partners” (Figure 2,3).

Similarly, 3% of surveyed Japanese farmers indicate that “Income declined due to abandonment of farm products and relinquishment of manufacturing and production due to foreign countries' import controls and trading partners' refusal to import Japanese products” (Figure 2). The later share for farmers in Fukushima prefecture is almost three times higher.

Combined impact on agricultural production has been generally negative for all major products in Fukushima prefecture and Tohoku region (Figure 8).



Source: Statistical yearbook of MAFF

Figure 8. Dynamics of major productions in Tohoku region, 2011 comparing to 2010 (%)

Farmers and agri-businesses from non-contaminated regions have got positive effects on businesses due to increased prices, and better production and sales opportunities.

Table 6: State of agricultural product damages in areas affected by the nuclear disaster

	Vegetables	Livestock	Fruit	Rice	Regional (Total)	Fukushima prefecture
Evacuated/restricted area share (%)	42.4	68.0	48.9	35.9	-	-
Evacuated/restricted area (100 million yen)	225	346	135	371	1,077	2,568
Evacuated/restricted area ratio (%)	8.8	13.5	5.2	14.4	41.9	100

Source : The Tohoku Department of Agricultural Administration, MAFF Statistics

Official estimates on total product damages from accident accounts for 2,568 billion yen in Fukushima prefecture (Table 6). They cover damage of unsold products (planning&distribution restrictions), and value losses caused by rumors. “Stock damage” (material funds, damage to production infrastructure, contamination of agricultural land,

facilities for evacuation, usage restrictions on machinery) and loss of “society-related capital” (tangible and intangible investments for creating production areas, brands, human resources, network structure, community, cultural capital, ability to utilize resources and funds for many years) are not included.

In May 2012 amount of compensation from TEPCO demands reached 62.5 billion yen with greatest portion of claims being for untilled land (compensation for suspension of work) and horticulture (Table 7). The amount of money received as compensation for the same period accounts for 73% of claimed damages. Latest figures shows that demanded compensation in Fukushima is 109,200,000,000 yen and received compensation are 97,200,000,000 yen (89% of demand). Most claims are for horticulture and livestock damages. According to experts compensation payments to farmers in neighboring prefectures is at lower rate - in Miyagi prefecture 50%.

Table 7. Breakdown of Compensation Claims in Fukushima Prefecture (100 million yen)

Claims	On May 1, 2012		On May 1, 2013	
	Value	Share in total (%)	Value	Share in total (%)
Rice	11	1.8	32	2.9
Horticulture	130	20.8	264	24.2
Fruit	62	9.9	75	6.8
Milk	18	2.9	20	1.8
Livestock disposal	99	15.8	100	9.2
Other livestock damages	85	13.6	162	14.8
Pasture	27	4.3	50	4.6
Untilled land (for work suspension)	163	26.1	325	29.8
Business damages	30	4.8	64	5.8
Total	625	100	1,092	100

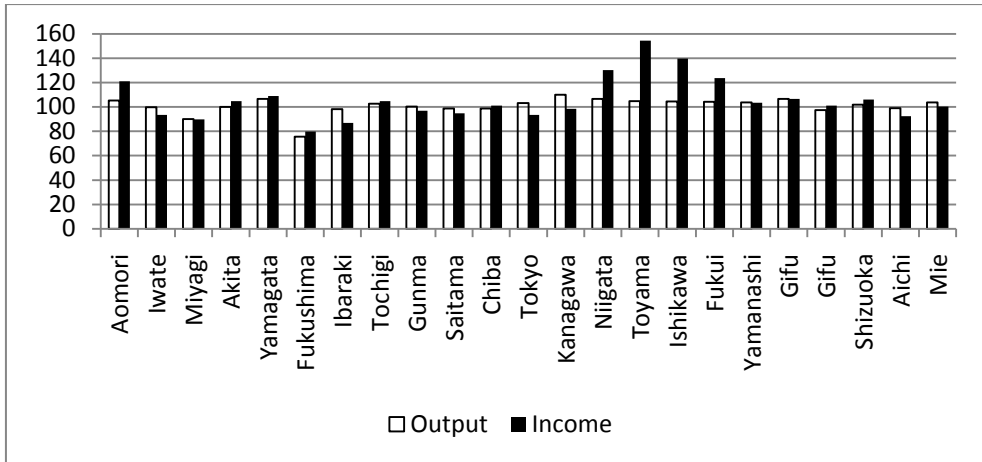
Source : Central JA Union for Fukushima Prefecture

TEPCO continues to receive claims for damages of farmers and agri-food business from around country. Total amount of claims received by and paid to affected agents is not available.

For farmers and agriculture cooperatives in Fukushima major issues related to compensation of damages are: three month delays in payment; not paying full claimed amount; disputing nuclear origin of damages; denying claims from voluntary restrains (production&distribution); claims related to farmland and property damage; compensation for business discontinuation; closing date issue is not decided; insufficient amount of compensation to restart farming; additional (inspection, administrative, radiation map preparation, support) costs and damages of farmers organizations not specified (Koyama, 2013; Nagashima, 2013). Difficulties experiencing by some older age farmers (paper works) is also pointed (Ishii, 2013). Efforts of farmers who did not market their products through cooperatives are particularly big. “Safety test” costs currently incurring by farmers and consumers and due to be compensated in unclear future, is also problem. There are problems with standard compensation, including differences in amount of products per are, farming method (organic, conventional), unlike value-added.

Food processing companies are receiving compensation on lost income according to Government guidance. Procedures are quite costly and associated with great paper works, hiring layers, lengthily negotiation.

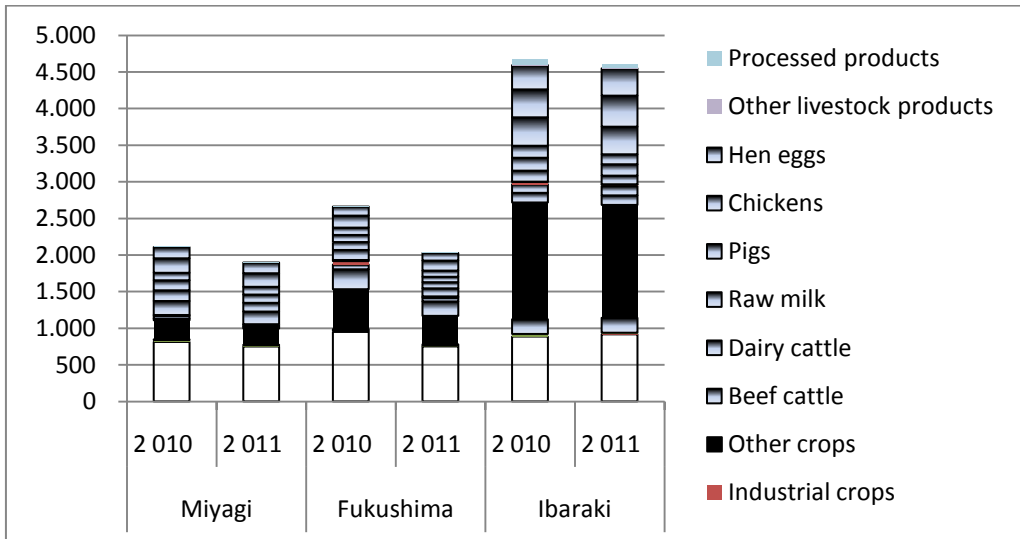
Nuclear crisis has got unlike aggregate impact on agricultural output and income in different regions (Figure 9). During period when Japanese agriculture was progressing in Fukushima and Miyagi prefectures there was considerable decline. Later was combined with sizable reduction in total income. Farmers in some other prefectures in region have seen their income significantly increased far above augmentation of total output.



Source: Statistical yearbook of MAFF

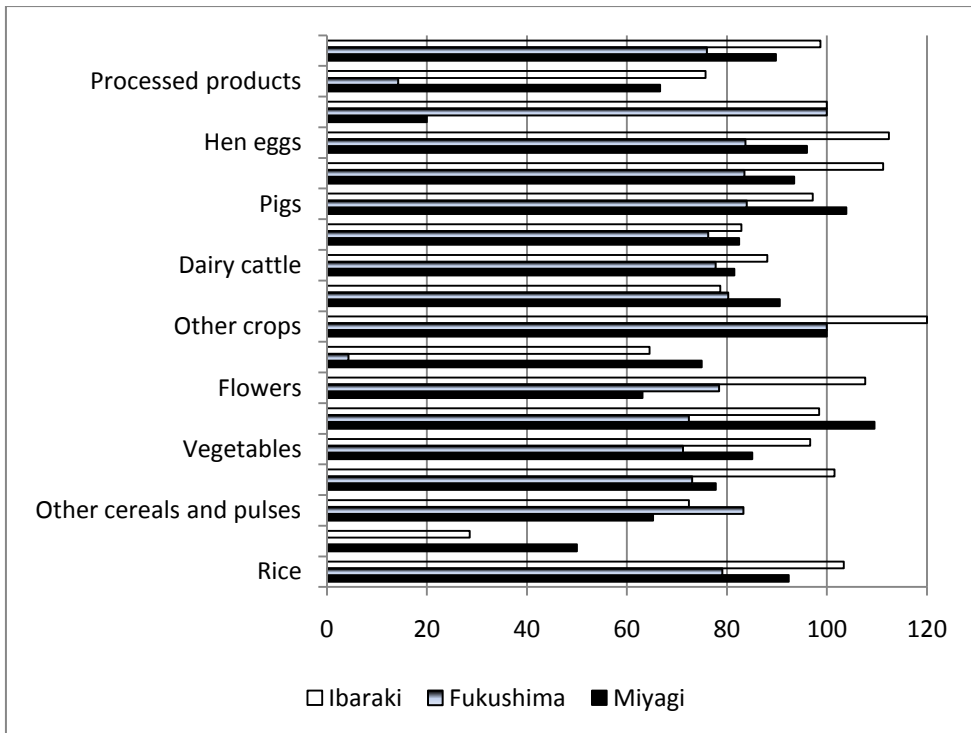
Figure 9. Dynamics of agricultural output and income, 2011 comparing to 2010 (percent)

Biggest decline in farm outputs was in Fukushima Miyagi and Ibaraki prefectures (Figure 10). Due to decrease in production and/or farm gate prices there was 24% decline of output of Fukushima farms. For major products like rice, vegetables, fruits, industrial crops, raw milk and cattle meat drop off were considerable (Figure 11).



Source: Statistical yearbook of MAFF

Figure 10. Dynamics of farm output in most affected prefectures (100 million yens)



Source: Statistical yearbook of MAFF

Figure 11. Index of major farm outputs in most affected prefectures (2010=100)

Due to undertaken private, collective and public measures there was not significant impact on profitability of farms. While in Ibaraki and some other prefectures share of agricultural income in output declined, in most prefectures that share either did not change or even improved (Fukushima).

Food industry in Fukushima and neighboring regions has been severely affected by accident. Recent survey of 55 food industry companies in Fukushima prefecture show that three quarters of them have seen sales declined after accident (Table 8). In 40% of companies 2012 sale decreased comparing to 2011. Consequence of declined sales, prices, restriction in shipment, and/or increased costs, more than 83% of companies report decrease in income. Great part of companies with no income changes say that is result of received compensations.

There has been great negative economic impact(s) on final consumers in affected regions and Japan in terms of increased direct (higher prices, procurement costs) and transactions costs (information, searching, assurances) for supply of safe agri-food products from alternative regions and/countries or guaranteed sources.

There have been number of positive effects on farms and business associated with disaster. There has been increased public (national, prefectural, local) support to farms and agri-business in affected regions. By March 2012, agricultural damages payments from Nuclear Damage Liability Facilitation Fund totaled 106.2 billion yen (MAFF, 2013).

Table 8. Impact of Fukushima nuclear disaster on food industry companies in Fukushima prefecture

Sub-sectors	Companies with changes in sales					Companies with changes in income			
	No	Decrease				Increase	Increase	Decrease	No
		≤ 10%	11-20%	12-30%	31-40%				
	7.3	29.1	23.6	21.8	5.4	12.7	3.6	83.6	12.2
grocery, milk, fermented milk drink, wrapping									
pickles, canned food, bread, confectionary, noodles, ramen, liqueurs, sake, flours, soya source, chicken and pork meat									
ramen, pickles, and delicatessen, milk and milk drink, chicken meat, flours, delicatessen, fruits and vegetables, wrapping									
pickles, honey, peach, cucumber, dried persimmon, sake, noodles, beer, milk and yogurt, kimchi, chicken meat, soya sauce									
cut vegetables, miso, pickles, fish processing, sake, ice cream and frozen desserts, konnyaky and tokoroten, meat									
meat, konnyaky and tokoroten, liqueurs									
pickles, ice cream and frozen desserts, honey, ramen, delicatessen, flours, noodles, confectionary, sake, peach, cucumber, dried persimmon, milk, milk drinks, yogurt, chicken and pork meat, beer, soy source, miso, cut vegetables, Grocery, noodles, sake, wrapping,									

Source: Fukushima Food Industry Organization, February 2013 survey

There has been easing in approval standards under the Agricultural Land Act and other laws, and one-stop procedure for zoning, approval and project planning introduced in affected areas. There has been huge public support for all decontamination efforts – national budget for decontamination for 2012-2013 comprises 1.1482 trillion yen (Koyama, 2013).

Further enlargement of loans with a credit line of 100 billion yen and interest-free loan was introduced. Farms having 30% and more harvest reduction and over 10% of property damages can apply for 2 million yen for persons and 20 million yen for companies with 3-6 years redemption period. For special cases individual loans have 2.5 million yen ceiling and extending period of redemption 4-7 years (MAFF, 2013).

There has been also significant support from diverse agricultural (cooperatives), business, academic, non-governmental etc. organizations. All they intensify their activities in affected regions and multiply relations with individual farmers and agri-businesses. That has been associated with increased “outside” service supply and likely positive effects on activity, innovations, incomes.

Great East Japan Earthquake and nuclear disaster considerably impacted citizens’ consciousness on food security policies. This disaster has prompted more 34.3% of consumers to “become conscious of need of food storage” on top of another 34.5% who “remained conscious with that need” (MAFF, 2012). Great part of consumers has strongly recognized importance of different food supply arrangements.

There are number of challenges in public support response most important being: delay in establishing Reconstruction Agency (February 2012) for coordinating multiple recovery efforts in affected areas; lack of clear government guidelines for nuclear disaster recovery, lack of detailed contamination map for all affected farmlands, using extension officers for obtaining samples for monitoring tests while suppressing ability of management consulting, introducing technology, and forming areas of production badly needed by farmers in affected areas (Koyama, 2013).

In some places there were problems associated with effective disposal of contaminated soils, ashes of burned household garbage, livestock etc. due to lack of enough facilities and/or strong objections by residents (The Mainichi Daily News, 2012).

Enormous public funding and novel business possibilities/restrictions have created new opportunities for revitalization and expansion of farming and agri-business in most affected regions and beyond. There have been huge incentives for investment in soil decontamination, emergency aid, agri-food safety, production recovery and modernization, product and technologies innovations and diversification, agri-food marketing, reconstructing of business and infrastructure, other public and private research and development projects. All there are opening up more entrepreneurial, employment and income opportunities for agricultural and general population.

In 2013 some producers have resumed experimentally rice growing in order to revitalize farming in areas where restriction are lifted (Ishii, 2013). Some entrepreneurs have seen new business opportunities in most contaminated areas such as hydroponic vegetable factory, bioenergy crop etc. productions. According to experts there are many companies (from outside areas) wanting to lease-in abandoned farmland and start large scale corporate farming.

2.7. Health Effect

Levels of radiation exposure of population varied according to direction from Fukushima plant. On March 16, 2011 MEXT measured radiation levels up to 330 $\mu\text{Sv/h}$ 20 km North-west of power plant (NHK, 2011). Level of radiation has been decreasing since. People living and working in different location are exposed to diverse levels of radiation. Even in same locations radiation level often differs due to different precision of instruments or local hot spots.

Thanks to undertaken measures radiation remained well below norms for damaging human health. According to official report 180,592 people in general population were screened for radiation exposure in March 2011 and no case found which affects health (NISA, 2013). Other reports also states that no confirmed long-term health effects had been reported as result of radiation exposure (IAEA, 2011). Recent report of WHO anticipated that there would be no noticeable increases in cancer rates for overall population, but somewhat elevated rates for particular sub-groups (NII, 2013).

According to local residents cases of diverse complains and hospitalization in Fukushima has been increasing since disaster. It was recently announced that estimates for radioactive exposure were wrong for 16,118 out of around 420,000 people covered by survey in first months after disaster, 12,460 of them received higher doses than previously estimated some getting more than annual safety limit (The Japan Times).

It is believed that the health effects of radiation release have been “primarily psychological rather than physical”. People who have been evacuated have suffered from depression and other mental health effects (Brumfiel, 2013). Consumers “lose peace of mind” having food with (lower than official safety limit but nevertheless) radiation contamination. Due to deficiency in inspection system there is no guarantee that contaminated food does not enter supply chain (Koyama, 2013).

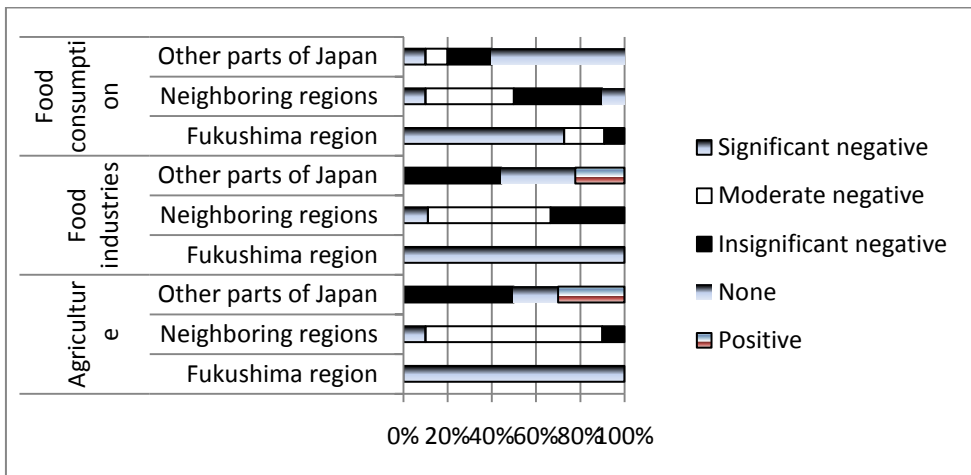
Many farmers from the area and beyond whose saw their businesses and livelihood destructed suffered stress and anxiety (Murayama, 2012; Watanabe, 2011). Old farmer in Sukagawa was pushed over the edge losing “everything he worked for during his life” and took his life.

“Health effect” on farm livestock and other domestic and wild animals is hardly to be assessed. Much farm livestock in most contaminated area has been slathered. Full impacts on health and genetics of living livestock and animals in other affected areas are to be examined in future.

3. Expert Assessments on Short and Long-Terms Impacts of Fukushima Nuclear Disaster

3.1. Levels and Factors of Shorter Terms Impacts

According to all experts nuclear accident has had a significant negative overall short-term impact on agriculture in Fukushima region (Figure 12). Most experts agree that the overall impact varies considerably according to the specific location of farms since living and working environment, contamination of farmlands and assets, restrictions on entry, production, shipping of produces etc. have been quite different in evacuation areas and in other parts of prefecture. Common view is that “in the areas of restriction to entry, stay and residence, recovery of agriculture remains difficult while other areas are affected by bad reputation”.



Source: Assessment by panel of experts, June 2013

Figure 12. Overall short-term impact of Fukushima nuclear disaster

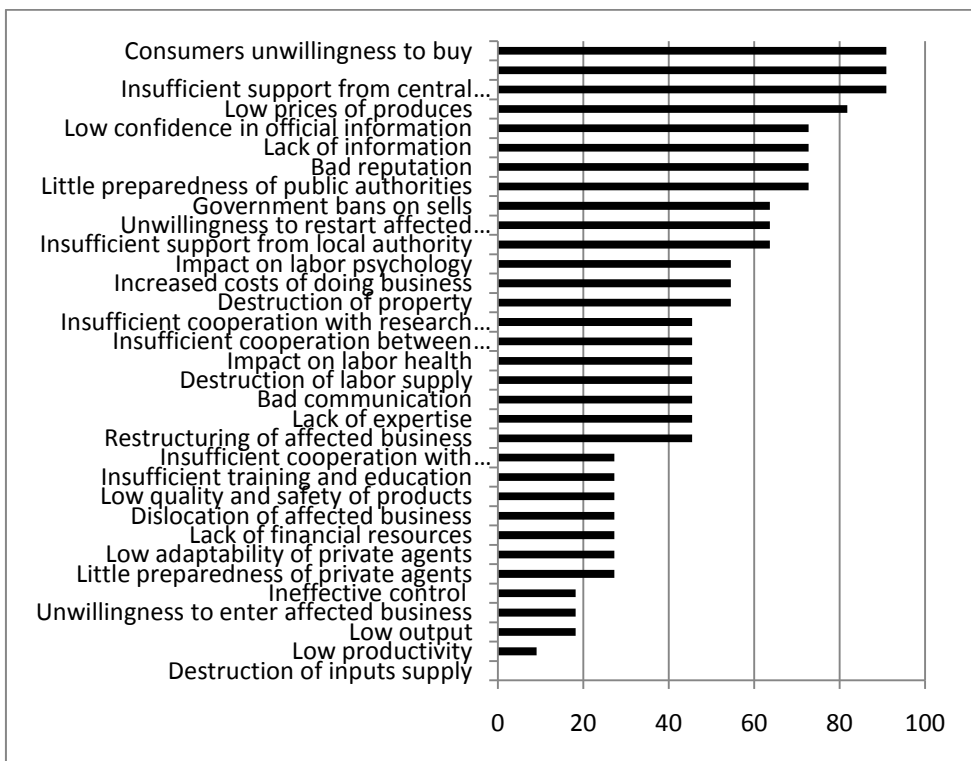
Significant majority of experts evaluate overall short-term impact on agriculture in neighboring regions as moderate negative. Impact in other parts of Japan is concerned i is estimated as insignificant negative or none by good part of experts. More than 27% of experts assess as positive overall impact of disaster on agriculture in other parts of country.

Overall short-term impact on food industries in Fukushima region is evaluated as significant negative. “Decreasing sales caused by contamination and harmful rumors” are major reasons for negative consequences on food industries in that region. Experts believe that “recovery of regional food industries will be faster than in agriculture in longer term”.

Negative impact on food industries in neighboring regions is mostly assessed as moderate while in other parts of Japan as insignificant or none. More than 18% of experts judge as positive overall short-term impact on food industries in other parts of country.

All experts evaluate as negative overall short-term impact on food consumption in Fukushima region. Great part of them assess that level of negative impact is significant. Biggest segment indicate that there is negative impact on food consumption in neighboring regions mostly assessed as moderate or insignificant. There is no short-term impact on food consumption in other parts of country. Good part of them evaluates short-term consequences as negative mostly as insignificant.

Most badly affected areas from nuclear disaster of agriculture in Fukushima region are: harmful rumors, shipping restriction, contaminated farmlands, decreased sales, unable and restricted farming, farming, lowered price of products, declined willingness to continue farming, works to prevent absorbance of radioactive matters, radiation inspections, polluted agricultural mountain products, compensation procedures, destroyed livestock in evacuation area, abolished products, destructed high brand local products, organic agriculture, agricultural management (decreased income), decreased values of farm assets, increased abandoned farmlands, moving farmers to other prefectures, declined consumption of local products by local people, secured market, external exposure to radiation, vegetables, rice, milk, beef, mushrooms, fruits. Some experts are concerned with “decrease of current and future farmers” as result of diminishing the willingness to farm and moving farmers to other prefectures as well as with “decreasing consumption of local products by local people”.



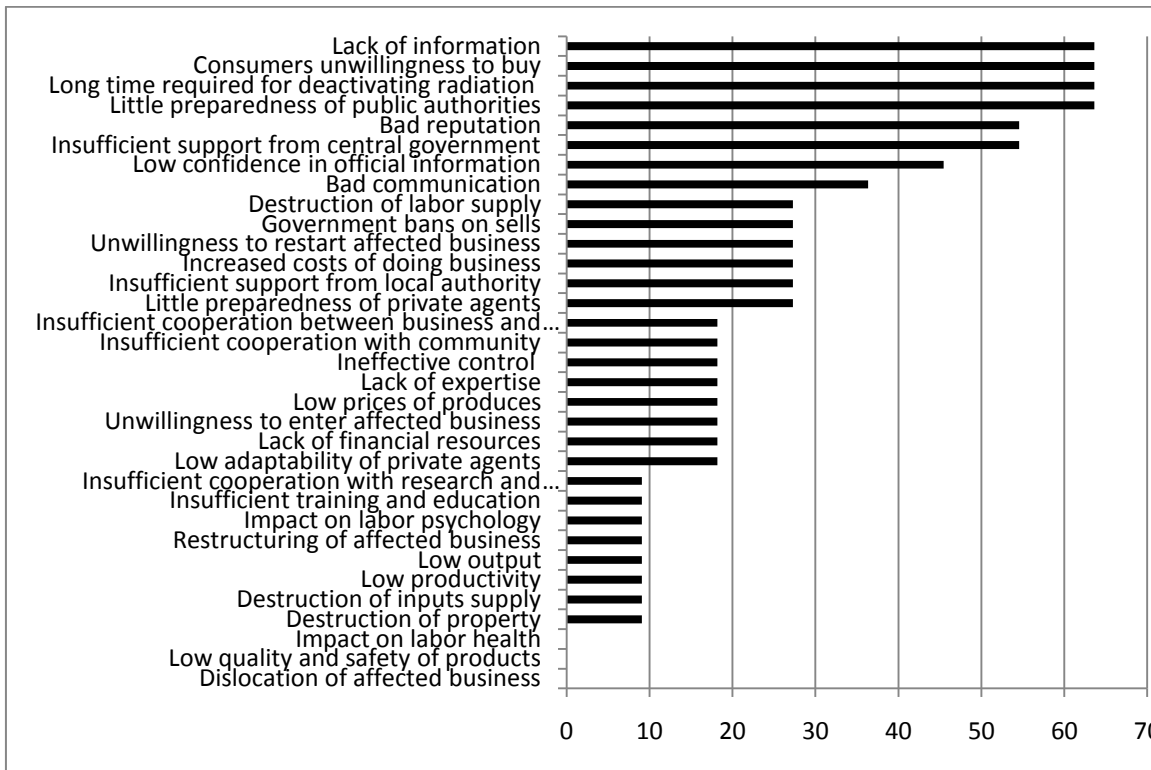
Source: Assessment by panel of experts, June 2013

Figure 13. Factors for persistence of negative impacts of Fukushima nuclear disaster on agriculture (percent)

Most badly affected areas of agriculture in neighboring regions are: harmful rumors, restriction of shipping, decreased sales, needs of inspection, anxiety about polluted farmland, gradual radioactive pollution, procedure for compensation, density of radioactive substance, vegetables, rice, milk, beef. In other parts of country most badly affected areas are: worries of radioactive contamination in East Japan, polluted agricultural products and mountain vegetables and little promotion made, declined exportation, restriction of shipping abroad, decreased sales, detected radioactivity in wild plants, beef.

Most badly affected areas of food industries in Fukushima region are: harmful rumors, decreased use of local ingredients, changed places for buying ingredients, increased costs, decreased sales, closed factories because of evacuation, unrecovered consumer trust, safety of local raw materials, excluding from tenders of local factories, decreased naming “Made in Fukushima”, management, seafood produces.

Most badly affected areas of food industries in neighboring regions are: harmful rumors, decreased sales, changes in buying ingredients, needs of inspection, inspection fees, worries of consumers, decline in exportation, density of radioactive substance, seafood produces. It is also mentioned that the food industry in these regions has been “more damaged from the earthquakes and tsunami than from the nuclear accident”. In other parts of country most badly affected areas are: restriction of shipping abroad, changes in buying ingredients.



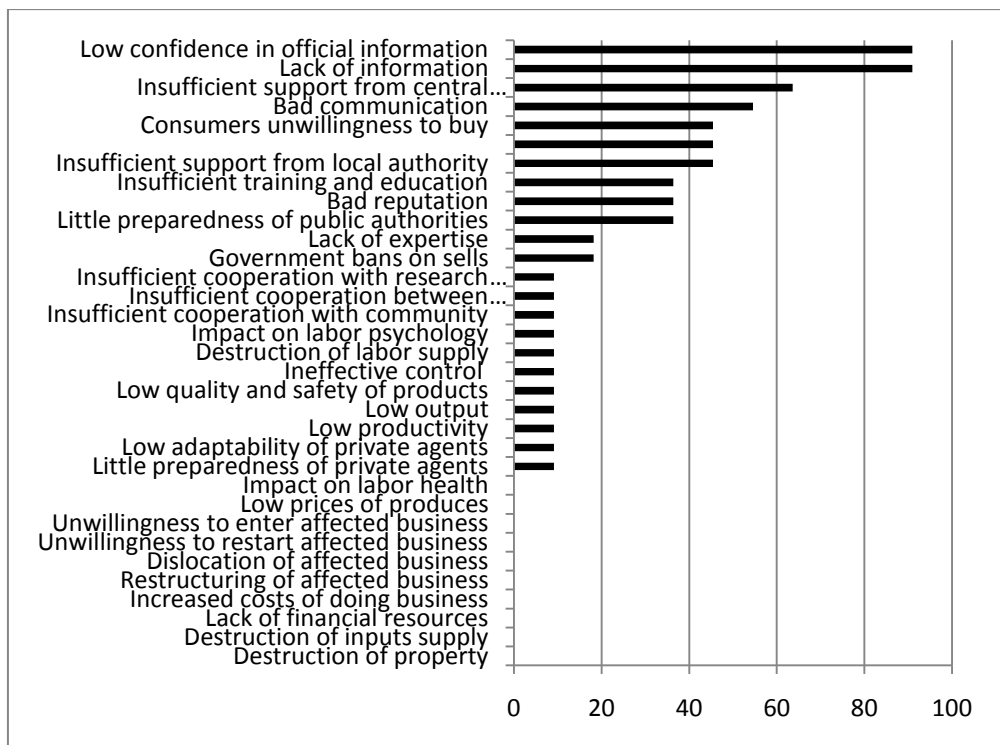
Source: Assessment by panel of experts, June 2013

Figure 14. Factors for persistence of negative impacts of Fukushima nuclear disaster on food industries (percent)

Most badly affected areas of food consumption from in Fukushima region are: avoiding Fukushima products, worries of radioactive contamination, stopped usage of local products for school lunch, increased costs for nonlocal supply, increased costs for buying water etc., declined population, the whole Fukushima area.

Most badly affected areas of food consumption in neighboring regions are: anxiety due to radioactive contamination, avoiding East Japan products, decreased consumption of local products, avoiding Fukushima products, harmful rumors, increased costs for buying water etc. Most affected areas in other parts of Japan are: avoiding East Japan products, avoiding Fukushima products, increased costs for buying water etc., increased anxiety.

Expert panel has identified the major factors for the persistence of negative impacts of the Fukushima nuclear disaster on agriculture, food industries and food consumption. Most important factor for persistence of negative impacts on agriculture are: “consumers unwillingness to buy”, “long time required for deactivating radiation”, “insufficient support from the central government”, and “low prices of produces” (Figure 13). “Low confidence in official information”, “lack of information”, “bad reputation”, and “little preparedness of public authorities” are also identified as significant factors for sustaining negative consequences in agriculture.



Source: Assessment by panel of experts, June 2013

Figure 15. Factors for persistence of negative impacts of Fukushima nuclear disaster on food consumption (percent)

Most important factors for persistence of negative impacts on food industries are: “lack of information”, “consumers unwillingness to buy”, “long time required for deactivating radiation”, and “little preparedness of public authorities” (Figure 14). “Bad reputation”,

“insufficient support from the central government” and “low confidence in official information” are also ranked as key factors for persistence of negative consequences.

Most important factors for persistence of negative impacts on food consumption are: “lack of information”, and “low confidence in official information” (Figure 15). Good portion of experts also believe that “insufficient support from the central government” and “bad reputation” are significant factors for sustaining negative impacts.

3.2. Longer Term Impacts

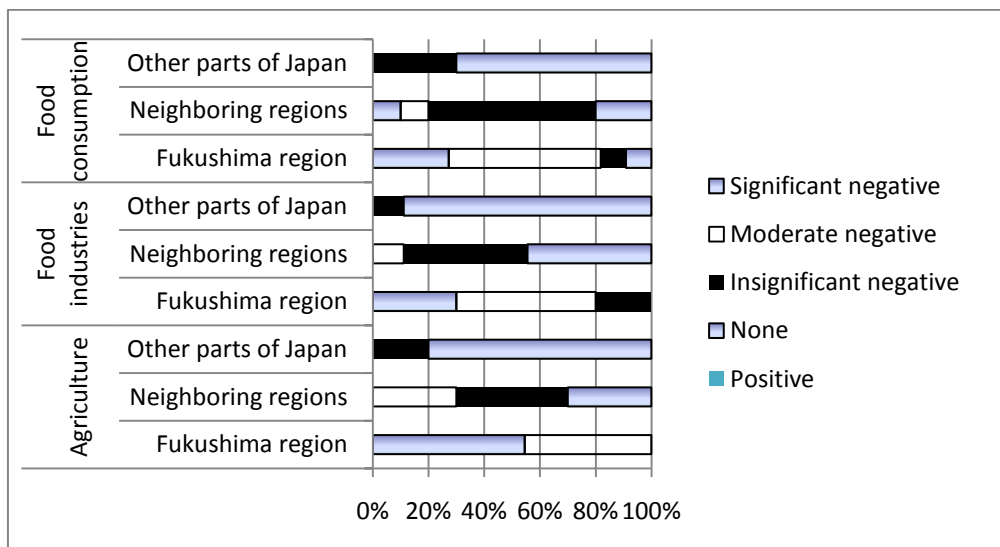
All experts think that overall long-term impact of nuclear disaster on agriculture in Fukushima region will be negative. Biggest part of assesses this impact as significant while rest evaluate it as moderate (Figure 16).

Most experts evaluate overall long-term impact on agriculture in neighboring regions as insignificant or none. Some good part believes that there will be moderate negative impact of disaster on agriculture in these regions. Overall long-term impact on agriculture in other parts on Japan is estimated as none by majority of experts.

All experts assess as negative long-term impact on food industries in Fukushima region. Most of them believe that effect will be moderate, some good portion ranked it as significant, while smallest segment evaluate it as insignificant.

Majority of experts estimate as insignificant or none overall long-term impact on food industries in neighboring regions. There is some part who believes that there will be moderate negative long-term consequences. Overall long-term impact on food industries in other part of country is predominately assessed as nil and small portion evaluate it as insignificantly negative.

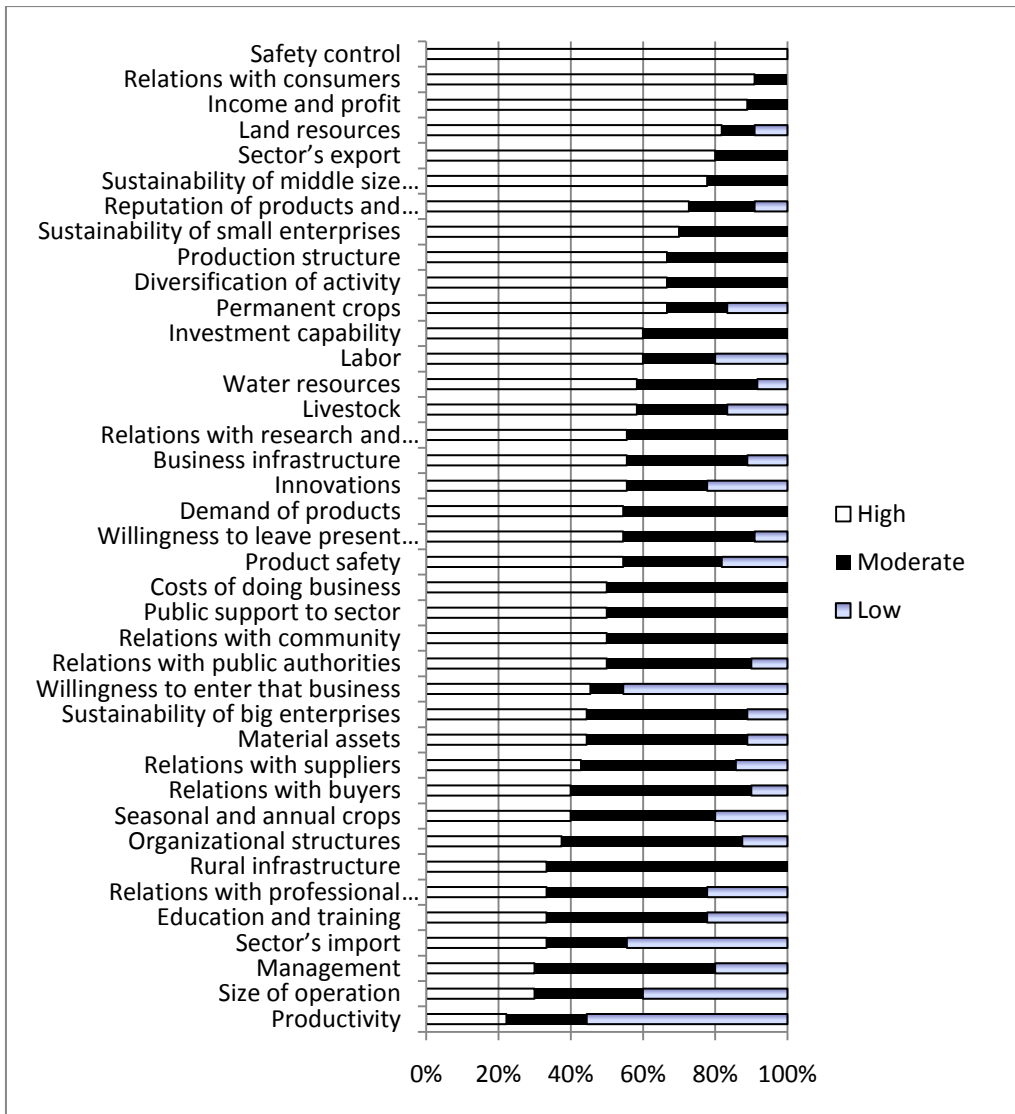
Great majority of experts think that overall long-term impact on food consumption in Fukushima region would be negative. Most part of them ranked is moderate but considerable portion assesses it as significant.



Source: Assessment by panel of experts, June 2013

Figure 16. Overall long-term impact of Fukushima nuclear disaster

Overall long-term impact on food consumption is predominately estimated as insignificant or none. One fifth of experts believe that there will be significant or moderate negative consequences. Greatest part of experts does not expect any long-term impact on food consumption in other part of Japan. Good segment assess overall long-term impact to be insignificant negative.



Source: Assessment by panel of experts, June 2013

Figure 17. Long-term effects of Fukushima nuclear disaster on agriculture

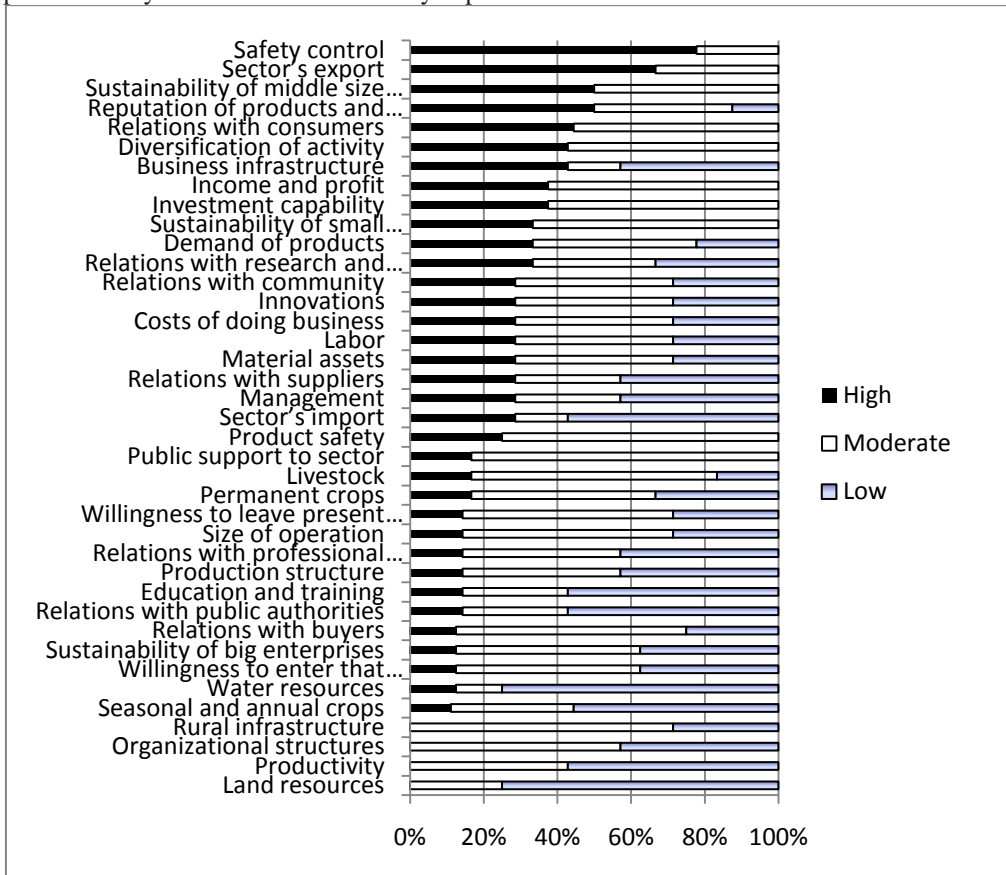
Experts are unanimous that there will be a high long-term effect on food safety in agriculture (Figure 17). They believe there will be significant effect on “relations with consumers”, “income and profit”, and “land resources” in this sector. There will be high or moderate effects on “sector’s export”, “sustainability of small and middle size enterprises”,

“reputation of products and services”, “diversification of activity”, “permanent crops”, “investment capability”, “labor”, “water resources”, “livestock”, “relations with research and education institutions”, “demand of products”, “willingness to leave present business”, “product safety”, “costs of doing business”, “public support to sector”, and “relations with community”.

Long-term effect on “rural infrastructure”, “relations with buyers”, “organizational structures” and “management” in that sector is mostly estimated as moderate. Nuclear disaster will have low effect on the “productivity” and “willingness to enter that business”.

Strongest long-term effect of disaster in food industries will be on “safety control” and “sector’s export” (Figure 18). There will be high and moderate consequences on “sustainability of middle size enterprises” and “reputation of products and services” in this sector.

Long-term effects on “sustainability of small enterprises”, “product safety”, “public support to sector”, “willingness to leave present business”, “size of operation”, “relations with buyers”, “relations with consumers”, “diversification of activity”, “relations with consumers”, “income and profit”, “investment capability”, “sustainability of big enterprises” and “willingness to enter that business”, “rural infrastructure” and “organizational structures” are predominately evaluated as moderate by experts.



Source: Assessment by panel of experts, June 2013

Figure 18. Long-term effects of Fukushima nuclear disaster on food industries

Long-term effects on “land and water resources”, “sector’s import”, “productivity”, “relations with public authorities”, “relations with suppliers”, “management”, and “education and training” in food industries is expected to be rather low.

4. Conclusion

This study is a first attempt to specify and assess multiple impacts of Fukushima nuclear disaster on Japanese agriculture and food chains. Research is not complete due to “short” period of time after disaster, shortage of comprehensive data, great controversy in information and opinions, and difficulties to adequately assess longer terms consequences. These weaknesses are partially compensated by wide use of diverse information sources as well as experts and stakeholders assessments. In future more interdisciplinary research is to be carried in order to properly understand and fully evaluate diverse impacts and factors of nuclear disaster on agri-food chains involving better precision, assessment of levels and interrelations etc. in larger temporal and spacial scales. That will be facilitated by increasing amount of available new data and publications on this important issue.

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