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Why did so few refugees return to the Fukushima fallout-impacted region after remediation? An interdisciplinary case study from Iitate village, Japan.

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1 **Highlights**

- 2 · Iitate Village in the residence-restricted area around Fukushima for 6 years
- 3 · Forest covering 74% of the surface area remain contaminated.
- 4 · Less than 10% of the population returned since the reopening in April 2017
- 5 · Priority to agricultural recovery although <2% of cropland is recultivated
- 6 · Difficulties to mitigate loneliness of returned inhabitants and lack of public facilities

7 **Abstract**

8 Large volumes of radionuclides were deposited on the soils in North-eastern Japan after the accident at
9 the Fukushima Dai-ichi nuclear Power Plant (FDNPP) in March 2011. The village of Iitate, with a population
10 of 6,544 inhabitants in early 2011, was located in the main radioactive plume. Its population was
11 evacuated between 2011 and 2017, when the town reopened after decontamination was completed in
12 some cultivated and residential areas. This situation is unprecedented in history. Even around Chernobyl,
13 access to the most contaminated area has remained forbidden until today. This manuscript compiles
14 measurements of radiation dose rates and sediment radioactive contamination, socio-economic statistics,
15 and reports the results of interviews conducted among refugees since 2011. Despite this reopening, which
16 was presented as desirable by the authorities, less than ten percent of the original population – almost
17 all of them over 70 years old – had returned to live in the village by January 2022. An analysis of the
18 evolution of the population shows that it is now declining again. When the village was evacuated in 2011,
19 most of the families that used to live with three generations under the same roof were often separated.
20 The majority of the inhabitants took refuge in neighbouring municipalities, and many lived in temporary
21 housing sites with a strong feeling of promiscuity. This study shows the difficulty for the majority of
22 villagers who had never heard of Becquerels before the accident in 2011 to return to a very different
23 environment with forests remaining contaminated and major landscape transformations having occurred
24 after several years of abandonment and through the remediation process itself. Before 2011, forests and
25 cropland were the main land uses in the village, and the local authorities promoted a model of eco-village.
26 While decontamination has been effective in limiting the dispersion of radionuclides across the landscape,
27 it did not affect the large stock of radionuclides stored in forests that cover ~80% of the surface area.
28 Moreover, the lack of facilities and public services remains problematic for an elderly population that has

29 a limited mobility to travel to nearby towns to find the necessities of everyday life. This study provides a
30 benchmark for comparison with the evolution of the seven other municipalities located nearby FDNPP
31 that are being reopened to settlement. This research, which shows the situation after a remediation
32 tentative, will provide a unique reference in post-accident management.

33 **Keywords** Nuclear accident; cesium-137; post-accident stress; Fukushima Dai-ichi Nuclear Power Pl
34 ant (FDNPP); disaster resiliency.

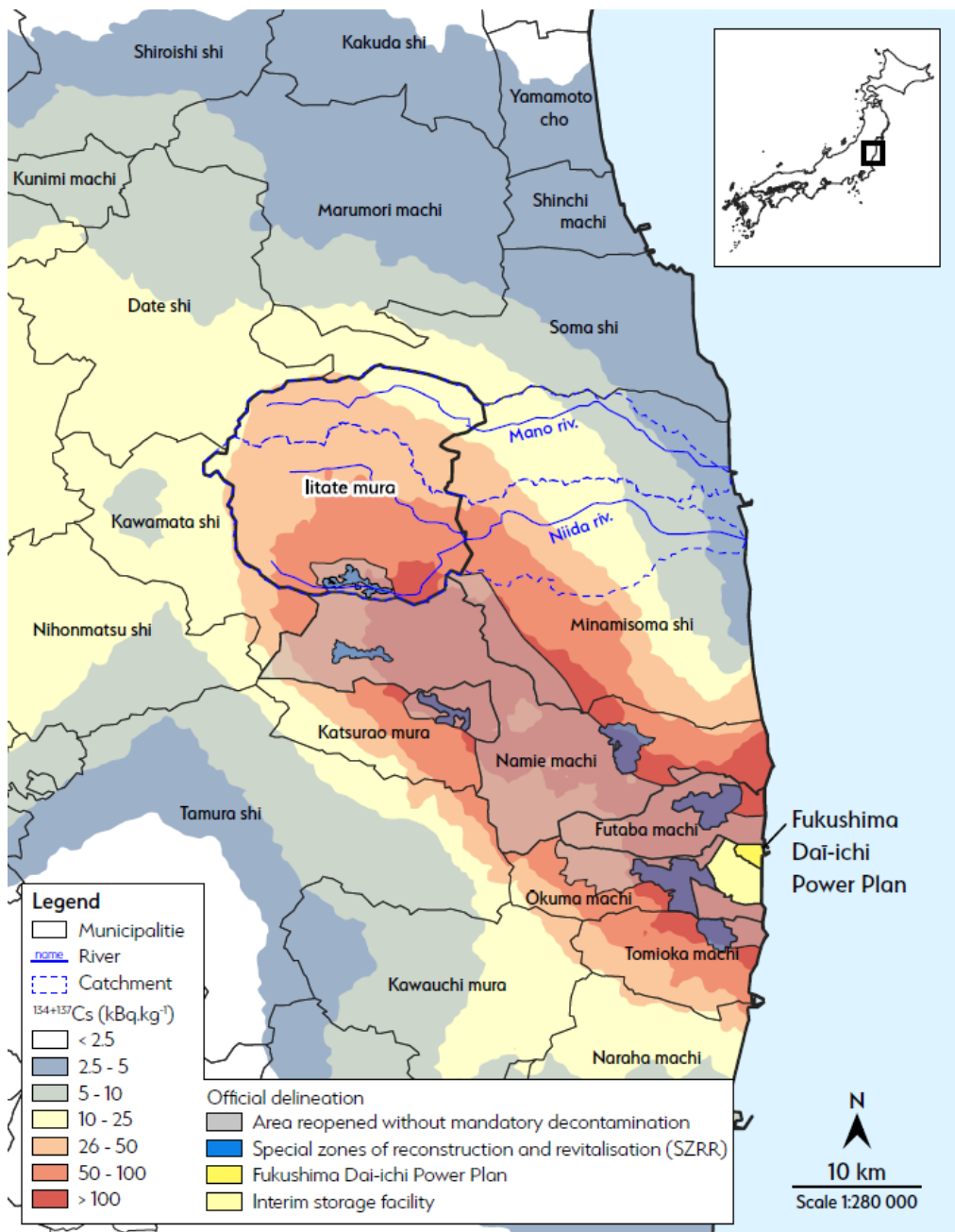
35

36 1. Introduction

37 The Great Tohoku earthquake that occurred on March 11, 2011 triggered a massive tsunami and an
38 unprecedented nuclear accident at the Fukushima Dai-ichi Nuclear Power Plant (FDNPP). Large
39 volumes of radionuclides have deposited on soils and formed a radioactive pollution plume extending
40 up to 70 km to the northwest of the FDNPP (Leelossy et al., 2011). Among the radioactive substances
41 released during the accident (Shozugawa et al., 2012), the main post-accident concerns are related
42 to the deposition of cesium-134 (^{134}Cs) and cesium-137 (^{137}Cs), which were emitted in abundance and
43 which are characterized by relatively long half-lives (2 and 30 years, respectively), causing their
44 potential long term persistence in the environment. The environmental contamination in the region
45 located to the northwest of the FDNPP has generated lively debates on the potential solutions to
46 implement to protect the populations living in this area (Asanuma-Brice, 2012; Asanuma-Brice,
47 2014).

48 In the main radioactive pollution plume of the Fukushima Prefecture, the Iitate Village (飯舘村)
49 represents an area of particular interest (Figure 1). This municipality has been classified since 2011
50 as a “Restricted Residence zone” until its reopening in 2017, after the completion of the remediation
51 work planned by the authorities on some cultivated and residential areas (Yasutaka and Naito, 2016).
52 However, the Nagadoro district (186 ha, 280 inhabitants before 2011), located in the southernmost
53 part of the village, is an exception, as it located in a zone where initial radiocesium levels exceeded
54 100 kBq kg⁻¹. Nagadoro district remain characterized as a “Difficult-to-Return Zone” (Figure 1). This
55 zone comprises one of the six “Special Zones of Reconstruction and Revitalization” (SZRR) of 186 ha,

56 set up in the Difficult-to-Return Zone, which is scheduled to be fully reopened by 2023. Following the
 57 revision of the Act for Special Measure for the Reconstruction and Revitalization of Fukushima (May,
 58 2017) the Japanese national government designated six SZRR (see Figure 1): Futaba Town in Sept.
 59 2017 (555 ha), Okuma Town in Nov. 2017 (860 ha), Namie Town in Dec. 2017 (661 ha), Tomioka Town
 60 in March 2018 (390 ha), Iitate Village in Apr. 2018 (186 ha), and Katsurao Village in May 2018 (95 ha,
 61 reopened on 12th June 2022, with 4 households - i.e. 8 inhabitants, all over 70 years old).



62

63 Figure 1. Location of the Iitate Village municipality, in the main radioactive pollution plume of Fukushima
64 Prefecture, in Northeastern Japan, and the main rivers (i.e., Mano and Niida Rivers) draining the village.
65 Background radiocesium ($^{134}\text{Cs}+^{137}\text{Cs}$) contamination map in topsoil (upper 5-cm layer) derived from Chartin et
66 al. (2013) and decay-corrected to 14 June, 2011. Official delineation of the main zones defined by the Japanese
67 authorities as of April 2022.

68 Numerous studies have investigated the fate of the radioactive contamination in the environment,
69 including in the soil (Yasunari et al., 2011), in sediment transiting the rivers (Nagao et al.,
70 2013)(Taniguchi et al., 2020; Ueda et al., 2021), in the vegetation (Kato et al., 2012) or the social and
71 political issues in this municipality (Asanuma-Brice, 2017a; Asanuma-Brice, 2017b; Munro, 2013). The
72 originality of the current interdisciplinary approach consists in complementing all this research with
73 the results of the authors' field surveys carried out since the FDNPP accident (2011–2022). During all
74 this period, we followed step by step the inhabitants and the different management policies for
75 promoting their return in order to analyze its consequences for the local population (economic, social
76 and health consequences, including psychological effects).

77 In this context, several arguments plead in favor of the choice of Iitate Village as a research area.
78 First, the administrative boundaries of the village coincide with the divide lines of two catchments,
79 which are those areas of land where precipitations collect and drain into a common outlet.
80 Accordingly, upper sections of the Niida and the Mano Rivers drain the land of Iitate (Figure 1). Those
81 situations where geomorphological and administrative units share the same borders are not so
82 frequent, and their coincidence therefore provides an ideal framework to investigate both social and
83 environmental research questions.

84 Second, the completion of the remediation works in Iitate village in 2017 corresponds to an
85 unprecedented situation in history to date. As a comparison, the authorities of the Soviet Union took
86 the decision to restrict the access to the most contaminated area located around the Chernobyl
87 Nuclear Power Plant after the accident that took place in 1986, and this decision has been maintained
88 for several decades until today (Fesenko et al., 2022; Steinhauser et al., 2014).

89 Third, as mentioned earlier, this municipality was a “Restricted Residence Zone” (RRZ) across the
90 entire village (230 km²) between 2011–2017. In the RRZ, the annual integrated doses were comprised
91 between 20 and 50 mSv, entry and business operations were only partially permitted and staying
92 overnight was prohibited. These restrictions were applied during six years before the ban was lifted
93 in April 2017. In contrast, the other municipalities exposed to the main radioactive fallout were either
94 fully reopened to the population (e.g. Minami-Soma), or they remained closed both day and night as
95 they were referred to as the “Difficult-to-Return Zone” (e.g. Namie Town; Figure 1). The surface
96 remaining classified as such covers 337 km² (as of April 2022). As the government plans to reopen
97 the whole area from 2023 onwards, the current interdisciplinary evaluation is therefore particularly
98 timely. The analyses related to the psychology of risk and the associated evaluations in terms of
99 cognition, emotion and action underlie the social component of this work (Breakwell, 2007). The
100 disintegration of ideal life models and the loss of reference points associated with the loss of material
101 goods and social link also underpinned our approach.

102 The current research compiles the qualitative and quantitative results of field monitoring surveys,
103 official document analyses and residents’ interviews conducted in Iitate Village between 2011 and
104 2022. The main objective of this study is to provide an interdisciplinary benchmark scientific
105 assessment of the situation, after the evacuation order has been lifted, as other municipalities will
106 undergo the same transition in 2023. To this end, data obtained by the means of ethnographic and
107 sociological analysis methods will be combined with those generated by environmental science
108 specialists in order to understand why so few refugees returned to their hometown after the
109 reopening of their village.

110

111 **2. Materials and methods**

112 As all the municipalities affected by the nuclear disaster, the village of Iitate was confronted to a
113 composite and complex situation. Interdisciplinarity is therefore essential to develop adapted tools
114 for understanding the situation and avoid the risks of pitfalls that may be caused by individual
115 approaches. This is why this research proposes and assumes a multidisciplinary approach allowing a
116 complete understanding of the situation.

117 2.1. *Eco-Geographical presentation of the study site*

118 Iitate Village (230.13 km²) is located in the eastern part of the Fukushima Prefecture in the middle of
119 the *Abukumakōchi* mountains reaching 918 meters at *Mount Hanatsukaya*, which is the highest point
120 of the village. Forests are the main land use in the area and provide a rich habitat for a mix of
121 broadleaf and coniferous trees including beeches, oaks, maple, keyaki, harigiri and firs. According to
122 public data from the Japanese Meteorological Agency, monthly temperatures vary from an average
123 of - 6°C in winter to +28°C summer (1991–2020) while the mean annual precipitation reaches ~1400
124 mm (Lacey et al., 2015). Heavy rainfall is concentrated between July and October, with 82% of the
125 annual erosivity supplied during these months, and with the occurrence of an average of 2 tropical
126 storms or typhoons on average each year (Evrard et al., 2020).

127 The village was particularly exposed to the radioactive fallout transported by the winds from the
128 FDNPP on March 14, 2011, and the occurrence of rain and snowfall on the night of 14–15 March led
129 to significant radionuclide deposition on the local soils and vegetation (Kinoshita et al., 2011).
130 Radioactivity levels are strongly variable across the municipality, from ~10 kBq kg⁻¹ of ¹³⁴⁺¹³⁷Cs in the
131 northern part of the village to more than 100 kBq kg⁻¹ of ¹³⁴⁺¹³⁷Cs in topsoil (upper 5-cm layer) of the
132 southernmost part, in Nagadoro district (Figure 1) (Chartin et al., 2013).

133 2.2. *Methodology for demographic, cultural and socio-economic characteristics of the village*

134 Official archives, documents and statistics from the Fukushima Prefecture and the municipality of
135 Iitate Village were analyzed and associated with the local residents' narrative (which will be referred
136 later in the text) in order to reconstruct the cultural situation and the socio-economic activities in the
137 village, both before and after the nuclear accident. The demographic evolution of the population was
138 also characterized based on national local official data (e.g. official population census of Japan). The
139 cost of the remediation strategies and the evolution of the local budget and the aids granted to the
140 refugees were also estimated, when available, based on official sources.

141 2.3. *Method of assessment of environmental contamination with radionuclides*

142 Annual fieldwork surveys were conducted between November 2011 and November 2020 along the
143 main rivers draining Iitate Village. During the field campaigns, radiation dose rates were

144 systematically measured in the field using a radiometer (LB123 D-H10, Berthold Technologies) in
145 recently deposited riverine sediment. The corresponding dose rates from the soils were calculated
146 based on data provided by the MEXT decay-corrected to the sampling date (Evrard et al., 2014; Evrard
147 et al., 2013). Only the results of three surveys (November 2011, May 2013 and November 2017) are
148 provided in the current study to illustrate the evolution of dose rates and their spatial patterns across
149 the municipality between 2011–2017, when the village was reopened to the inhabitants.

150 *2.4. Interviews of local residents and municipal authorities*

151 Interviews of ~50 local stakeholders were conducted on various occasions between 2011 and 2021.
152 Among the residents, four types of inhabitants were interviewed: (1) people who have returned to
153 live in Iitate, (2) refugees who continued to live in temporary housing in nearby municipalities when
154 it remained operational, (3) refugees in other regions/municipalities, and (4) refugees who continue
155 to work during daytime in Iitate. Specialists in charge of educational, agricultural and social affairs
156 were also interviewed at the town hall. Extracts from these open-ended interviews will be provided
157 throughout the text. The results of surveys organized by local newspapers and researchers are also
158 reported.

159 **2.5. Mapping the evolution of land use**

160 To complement land use information made available by the Japan Aerospace Exploration Agency
161 (JAXA, 2021), we carried out a systematic screening of the aerial photos available on Google Map in
162 2022 following their UTM grid based on the geodetic within the boundaries of Iitate Village. The
163 specific objective was to highlight the evolution of specific land cover features that are not captured
164 by routine land cover mapping and which are the main visible changes in the landscape in terms of
165 land use since the nuclear accident (i.e. contaminated waste disposal areas and solar panel fields).
166 These zones were delineated and the corresponding surface areas were also calculated.

167

168 **2.6 Limitations of findings**

169 In addition to the environmental consequences, the accident at the Fukushima Dai-ichi nuclear power
170 plant has been a catalyst for demographic processes that were often already initiated before 2011,
171 i.e. depopulation of the rural municipalities. Therefore, efforts to revitalize the region have limited
172 consequences for the time being, although it is difficult to assess whether this trend is due to the
173 contamination of the territory only (which undoubtedly accelerated and amplified the process) or

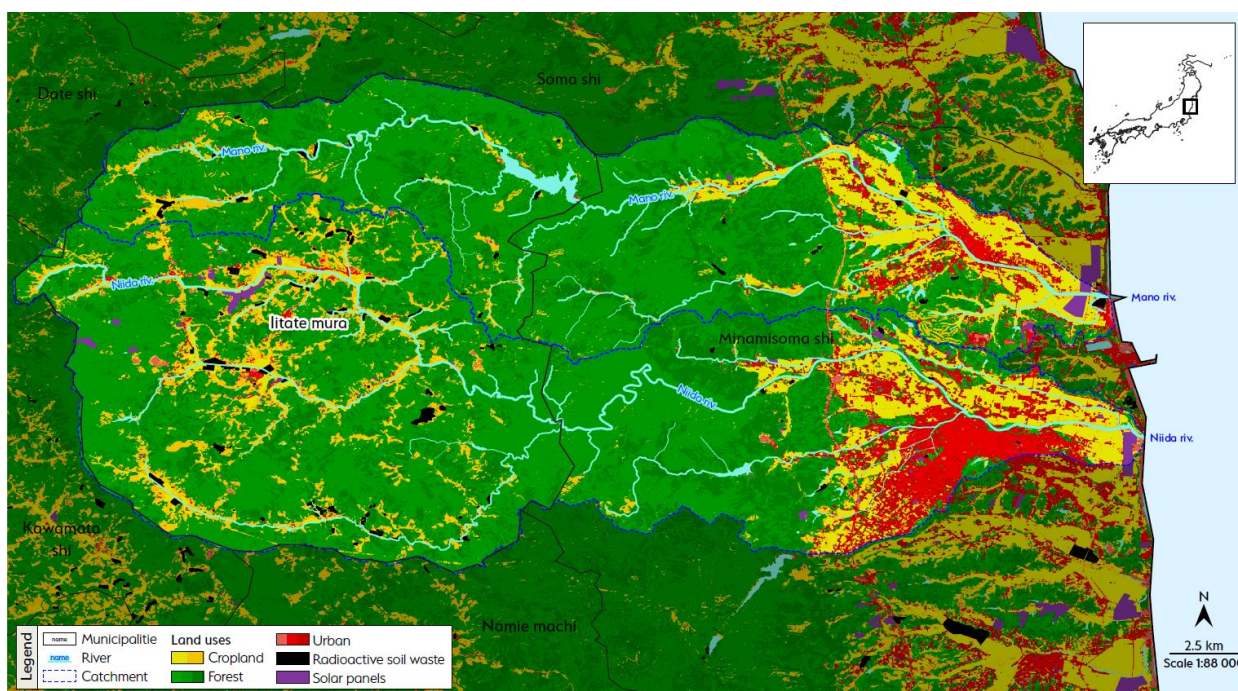
174 whether it would have been similar over the long term even in the absence of nuclear accident.
175 Nevertheless, drastic policies have been implemented, notably regarding the reuse of waste from
176 decontamination and, consequently, the reduction of the number of sites for storing contaminated
177 soil bags. It is therefore necessary to continue to monitor the situation over the long term in order
178 to capture the demographic trend.

179

180 **3. Results and discussion**

181 *3.1. Cultural and socio-economic characteristics of the village*

182 The village, which is subdivided in 20 districts, is mainly covered with forests (81.9 % of the surface
183 area, with 47% of these forests being owned by the Japanese State) and cropland (16.2%). The rest
184 of the land was mainly occupied by pasture and vegetable fields, with scattered settlement areas
185 across the landscape (Figure 2). The local population with a majority of farmers amounted to 6211
186 inhabitants before the FDNPP accident, which corresponds to a very low density (26 inh. km⁻² vs. 343
187 inh. km⁻² in 2010 at the scale of Japan). In 2010, paddy fields occupied more than half of the cropland,
188 the rest being cultivated with tobacco, vegetables and flowers. Grassland covered 1.97 km² (0.8%)
189 for cattle (black *wagyu* cows) and horse breeding, with a total of ~2000 heads of cattle in 2010 (Iitate,
190 2018). Another significant economic activity in Iitate was the production of timber. However, to meet
191 their needs, most farmers had sideline activities (e.g. production of traditional *bento*'s, of blueberry
192 jam and pastries, maintenance of forest in the mountains...)



193

194 Figure 2. Land uses and specific land cover features (i.e., solar panel fields, waste storage zones) after data
 195 from the Japan Aerospace Exploration Agency (JAXA, 2021) for the situation observed over the period
 196 2018-2020 and aerial images available on Google Earth (April 2022, this study).

197 This situation radically changed after the accident, when the village re-opened. From the 25.4 km²
 198 surface area cultivated before the accident, only 1.6% were exploited in 2020 (rice, buckwheat,
 199 flowers). Local experiments are being conducted to test the cultivation of rice and vegetables, among
 200 other crops, on limited surfaces (typically 0.01 or 0.02 km²). Timber cannot be produced anymore as
 201 it would be too contaminated, and the production of wood pellets for heating installations is
 202 prohibited (Evrard et al., 2019).

203 Despite its small size, the village had a rather diverse cultural and recreational life until March 2011.
 204 Listed among the “most beautiful villages of Japan”, Iitate’s lush countryside attracted students in its
 205 agricultural school. Fishermen caught carps and black basses in the rivers or in the Mano Dam
 206 Reservoir. Iitate is also rooted in the collective imagination of Japanese citizens, as it is referred to in
 207 Tatsuyuki Takanô’s famous song “*Furusato*” (Hometown). In addition to these specificities, those
 208 ancestral traditions found in the countryside across Japan, like the gathering of *sansai* (literally
 209 “mountain vegetables”) were widespread in the village.

210 Before 2011, the village's project was to set-up a "eco-village" model. The local authorities promoted
211 the installation of several experimental farms in charge of developing original environmental-friendly
212 farming practices. Among these institutions, *litate Farm* was managed by Mr. Nobuyoshi Itô who
213 accepted this position when he was 67 in 2010, just one year before the FDNPP. After the accident,
214 this farm was transformed into a site devoted to radioactivity measurements and decontamination
215 experiments. During 7 years, he carried out very diverse radionuclide measurements in a variety of
216 environmental samples including butterflies (Hiyama et al., 2012), honey, tree barks, branches and
217 leaves, or even rice. He received more than 800 visitors until the farm closed down in July 2018. "All
218 the green that you see here is cesium-green. You cannot find a single spot free of contamination", he
219 said.

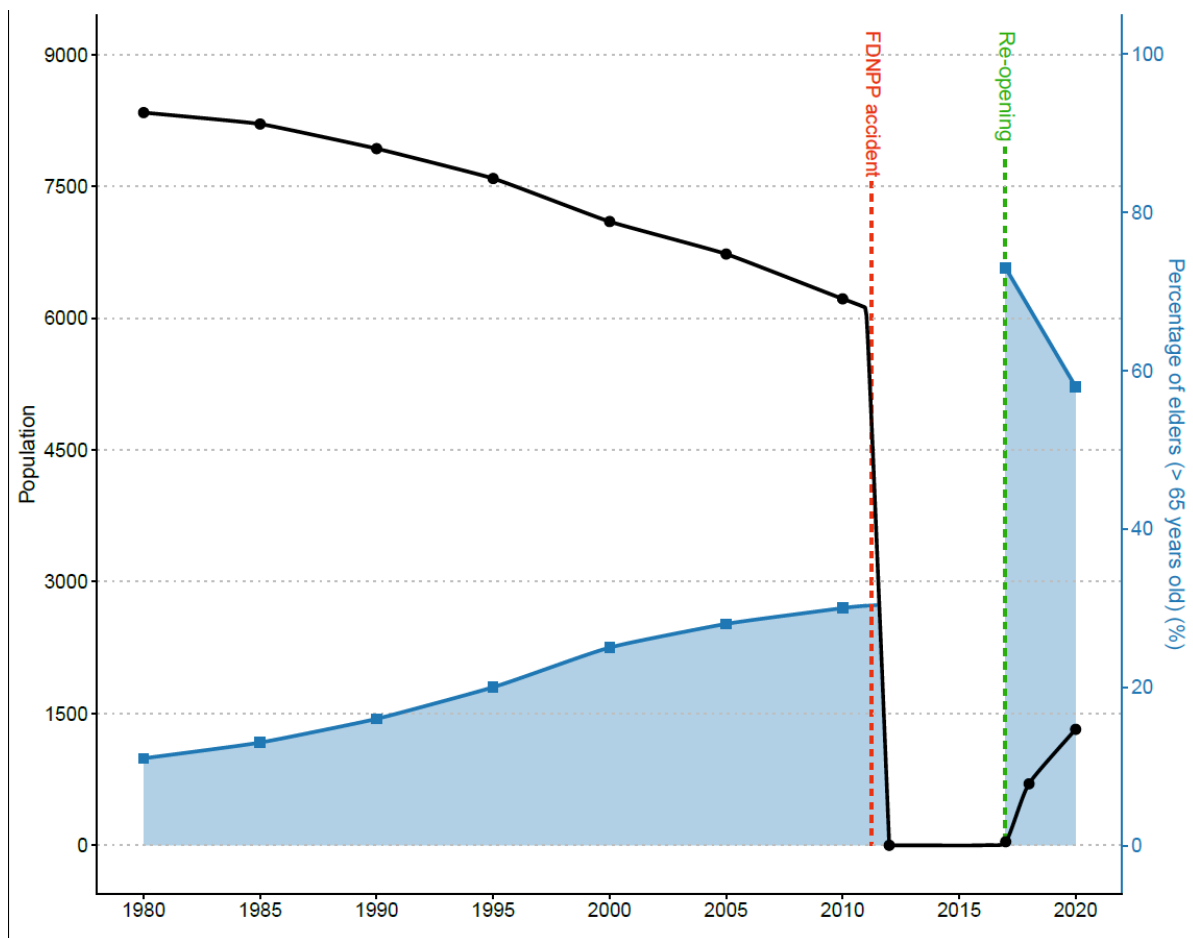
220 *3.2 Reconstruction of events during the accidental phase*

221 Despite the detection of high radiation dose rates (up to $45 \mu\text{Sv h}^{-1}$) in the region by the SPEEDI
222 (*System for Prediction of Environmental Emergency Dose Information*) system between March 11–15
223 (Nagataki et al., 2013), which the government had not access to at the time of the accident, the
224 evacuation of the population of litate Village began on April 22, 2011 after the changes in the
225 delineation of the restricted zone. Initially, a 20-km radius zone centered on the FDNPP was
226 evacuated before being extended to a 30-km radius zone and, finally, adjusted to the exact shape of
227 the radioactive plume extending to the northwest of the region (Figure 1). Most villagers actually
228 evacuated the village later, in June 2011. The measurement of radiation dose rates as high as $20 \mu\text{Sv}$
229 h^{-1} (i.e. $\sim 175 \text{ mSv yr}^{-1}$) in the vicinity of the houses during Spring in 2011 supported the decision to
230 evacuate (Imanaka et al., 2012). This evacuation was a rather chaotic experience for the villagers, as
231 they received a series of conflicting orders and information (Asanuma-Brice, 2021). The temporary
232 housing sites were only ready to welcome them by August 2011, and they had to find provisional
233 solutions staying at relatives or in *ryokans*. To this confused management, during which the
234 inhabitants were shuffled from one place to another, we must add the pain of the loss, certainly of
235 their former living place, but also of the animals that shared their lives until then. Furthermore, the
236 requirement for the families to kill their cows or their horses when leaving the village has been
237 reported as a traumatic experience by many local families.

238 3.3 Demographic evolution

239 Following a cycle of depopulation similar to that observed in the countryside of other developed
240 countries around the world, the decline in population is not recent in Iitate Village, as the population
241 decreased from 9385 inhabitants in 1970 to 6211 early in 2011 (Figure 3). Nevertheless, the way of
242 life had remained very traditional. In most families, three generations lived under the same roof, with
243 a mean of 3.6 persons per household, as 1700 households lived in Iitate. After the residence
244 restrictions issued in April 2011, families were often separated, as the size of the temporary housing
245 residences available was generally not sufficient to accommodate the entire family. Therefore, the
246 number of households increased by 77%, to 3008 units and the number of person by family
247 decreased to 1.8 persons per family.

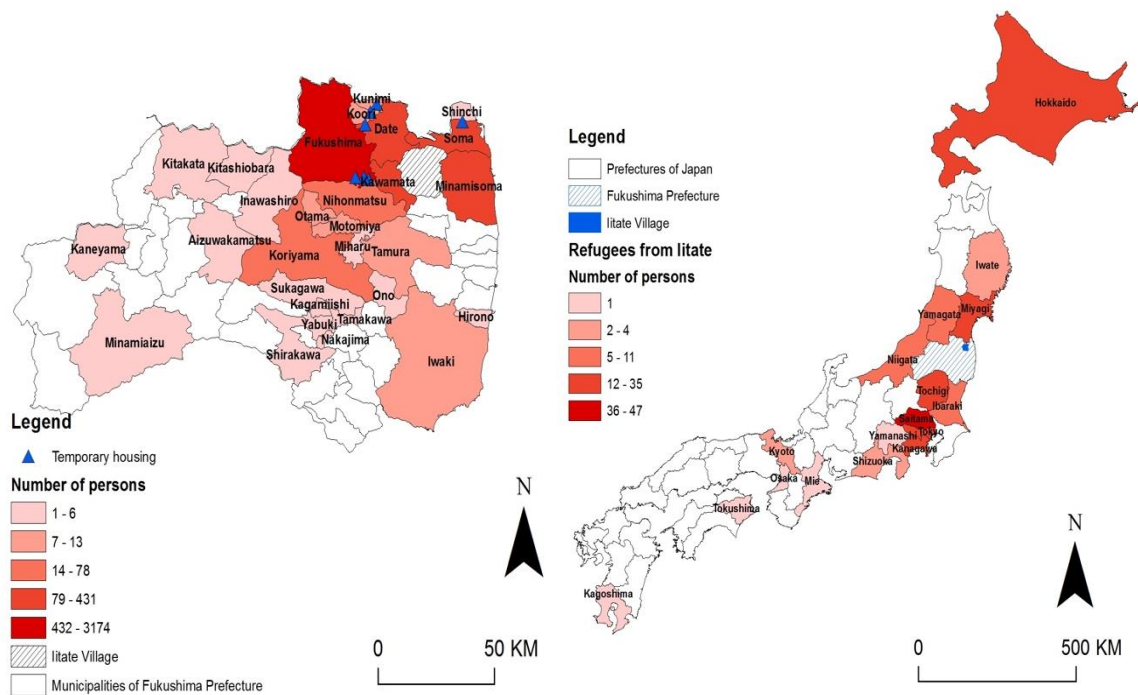
248 Of the 2476 households that migrated to other places located in the Fukushima Prefecture (82.3%)
249 in December 2016 (i.e. three months before the original date for withdrawal of evacuation subsidies),
250 467 were living in temporary accommodation, 100 were living in public housing, 935 were housed in
251 the private rental sector (with rent paid by the Japanese authorities) and 911 households acquired a
252 new house. Of the remaining households, 63 left no trace, lived in retirement homes or returned to
253 the village. A further 182 households moved outside of the Fukushima Prefecture. These data
254 illustrate the familial disruption induced by the small size of housing available to the refugees. *“With*
255 *the very low population density in the village, the houses were very distant from each other. Imagine*
256 *the stress and the containment feeling experienced by those people who moved to small-sized*
257 *temporary housing or flats. You have windows onto your neighbor and you hear everything in the*
258 *house next door... The situation was untenable for most of us”*, explained a refugee in Date. Many
259 households consist of only one elderly person, and an increased mortality was observed in this group.
260 In 2017, when the village was reopened to the residents, the population had dropped to 41. Early in
261 2018, slightly over 10% of the initial population, i.e. 700 individuals, had returned to the village
262 (Figure 3, Table A.1). In 2022, the population increased to 1476 individuals divided into 774
263 households, i.e. less than two people per household, which indicates a major transformation in the
264 way people lived together, since the majority of the returnees found themselves alone at home.



265

266 Figure 3. Evolution of the population and the proportion of elderly population (> 65 years old) in Iitate Village,
 267 from 1980 to 2020. Data available from the Japanese Ministry of Internal Affairs and Communications.

268 Among the initial residents of Iitate, 4934 persons divided into 2032 households sought refuge within
 269 the Fukushima Prefecture, with a vast majority in the City of Fukushima itself (3174 persons, 64.3%
 270 of the refugees; Figure 4a). Only 297 persons divided into 156 households took refuge outside of the
 271 Prefecture, mainly in the region of Tokyo (Figure 4b). In total, 90% of the initial population lived out
 272 of the village during 7 years and, among them, 546 persons distributed across 288 households
 273 planned to return to Iitate by March 1, 2018. For these persons who sought to come back to the
 274 village, their household composition (mean: 1.8 persons) suggests that they almost exclusively
 275 correspond to couples without children.



276

277

(a)

(b)

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Figure 4. Number and location of refugees originating from Iitate Village (a) in the Fukushima Prefecture and (b) elsewhere across Japan as of March 1, 2018. The location of the 9 temporary housing sites in the vicinity of Iitate Village is provided by the green triangle symbols in (a).

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Another question to investigate was the number of fatalities recorded during the 2011–2017 period, coinciding with the evacuation. In the Fukushima Prefecture, it was shown that more people died indirectly from the consequences (over a long period of time) than from these disasters themselves (i.e. the earthquake and the tsunami of March 2011). From the 4040 inhabitants of the Prefecture who lost life for reasons attributed to the catastrophe, according to the local newspaper, 1605 (39.7%) passed away following the natural disasters, while 2211 (54.7%) died from “stress or difficulties associated with the evacuation” (Ishida, 2018). On March 3, 2018, the headline of the local newspaper *Fukushima Minpō*’s frontpage was as follows: “at the heart of the shelter, more than 2211 fatalities directly resulting from stress”. However, we must point out that the controversies are still extremely tense on questions relating to the health consequences of the nuclear accident. For instance, one of the villagers of Iitate who agreed to answer our questions died of thyroid cancer in October 2021. Although a formal link is difficult to establish, we cannot fully exclude that there is a

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293 link between these cancers and the early exposition to radiation. The health commission in charge of
294 evaluating the thyroid cancers that have developed in the region is under great pressure to interpret
295 the results, which are likely showing an increase in the number of thyroid cancers in the sample of
296 370,000 children under the age of 18 (although the age limit also raises questions) at the time of the
297 accident, i.e. 301 children in May 2022. Nevertheless, the health commission concludes, despite the
298 anger of the inhabitants and other epidemiologists who were not part of the commission, that these
299 cancers are the result of over-diagnosis due to the increased sophistication of medical equipment
300 and a screening effect caused by systematic testing. This question therefore remains widely debated.

301 Another health effect that should not be neglected as it represents a factor explaining the increase
302 in deaths, exceeding that associated with the natural mortality of an ageing population, although it
303 is difficult to assess quantitatively, is depression and its consequences: alcoholism, overall physical
304 inactivity, malnutrition (some isolated elderly people stop feeding themselves), suicide, etc. For many
305 villagers who had spent their entire lives in the countryside, it was difficult to adjust to urban living
306 conditions for those who had to move to the city. Their new living environment were sometimes
307 fatal to them.

308 *3.4 Accommodation*

309 The lifting of the compensatory allowances in April 2017 encouraged most of the elderly persons with
310 low incomes to return to the small deserted village. Among the 4934 persons who sought refuge in
311 the Fukushima Prefecture, 384 of them, distributed across 233 households, were accommodated in
312 nine temporary housing sites that were definitively closed in March 2019. Although 363 persons (174
313 households; 8%) were relocated in public housing and 1053 persons (550 households) were resettled
314 in private housing with the rent being supported by the government, nearly half of them (3119
315 persons spread across 1060 households; 49%) were hosted by relatives. Fifteen isolated elderly
316 individuals lived in retirement homes. This raises the question of the meaning of "home".

317 The lack of privacy and the life in crowded environments were associated with the economic
318 dependence imposed by this type of community housing, with the need for this majority of farmers
319 to purchase all their food products and necessities, without the possibility to produce or cultivate

320 them in the vicinity of their new residence. On June 5, 2012, the regional newspaper *Seikei Tohoku*
321 released the results of a survey conducted among 1539 inhabitants from Iitate. Only 39.8% of the
322 interviewed agreed to reply (576 persons). Among the respondents, 445 (85.7%) were between 70
323 and 79 years of age, and 70% were men (Seikei, Tohoku, 2012). This questionnaire is extremely
324 enlightening of the stressful situation to which the inhabitants were confronted. Question 17 asked
325 the refugees which type of relationships they had with their family. 85.6% of them replied that their
326 links had deteriorated after the catastrophe. Question 18 addressed the medication use, and 65.1%
327 (375 persons) of the respondents stated that their drug consumption significantly increased. This
328 questionnaire also provided information on the refugees' plans to return to the village as of May,
329 2012: 49.1% of the respondents declared that they did not plan to come back, whereas 21.6% of
330 them wanted to go home after the general decrease of the radiation dose rates in the village below
331 1mSv yr^{-1} . This is crucial because, as previously stated, Iitate is a rural village, more than 75% of which
332 is covered by forests that cannot be decontaminated. Without decontamination, it will be necessary
333 to wait several more decades before radioactivity levels become acceptable again. Furthermore, the
334 risk of contamination run-off from the forest to the decontaminated farmland persists, and dealing
335 with this risk may require repeated decontamination campaigns in already remediated areas or the
336 application of potassium fertilizers to prevent the plants from fixing the residual radiocesium. In
337 addition, when the villagers were asked why they would not return to the village if they were allowed
338 to do so, 82.7% of the respondents replied that they were not satisfied with the remediation works;
339 74% thought that they could not trust the reassuring message of the authorities; and 67.5% argued
340 that they would not agree to return if it was impossible for them to restart an agricultural activity. In
341 2012, 63% of the respondents thought that it would not be possible for them to return to their homes
342 even after decontamination. Furthermore, 57% of the interviewed estimated that it was not
343 necessary to spend such a high budget on remediation (estimated to 300 billion yens or 2 billion US
344 dollars when the survey was conducted in 2012). Despite this dominant opinion expressed as early
345 as in 2012, Iitate was selected to be a model municipality for re-opening, and an ambitious
346 decontamination program was carried out in the village at an unprecedented scale (Evrard et al.,
347 2019).

348

349 *3.5 Effectiveness of decontamination*

350

351 Radiation doses measured on decontaminated soils measured on multiple occasions across Iitate
352 Village varied between 0.3 and 0.4 $\mu\text{Sv h}^{-1}$ (i.e. 2.6 – 3.5 mSv yr^{-1}), which remains higher although of
353 a similar magnitude than the mean annual dose due to the exposition to cosmic rays in Fukushima
354 Prefecture comprised between 0.20 – 0.50 mSv yr^{-1} or the total annual dose (including exposition to
355 ^{210}Po from fish products, ^{222}Rn in houses, etc.) estimated to a mean of $\sim 2 \text{ mSv yr}^{-1}$ (Hosoda et al.,
356 2016). Most decontamination works conducted in the village concentrated on the cropland in
357 general, and on the paddy fields in particular, with the removal of the 5-cm topsoil layer
358 concentrating the radionuclides (as demonstrated by Lepage et al. (2015) for several soil profiles
359 including five soil cores collected in Iitate). This generated very large quantities of decontamination
360 waste (with storage sites across the landscape covering up to 2.6 km^2 ; Fig. 2), which the authorities
361 plan to recycle in civil and road works for those material containing less than 8000 Bq kg^{-1} of ^{137}Cs ,
362 while the threshold value was fixed to 100 Bq kg^{-1} before the FDNPP accident. The multiple campaigns
363 of decontamination works could not fully remove the radioactive fallout deposited after the FDNPP
364 accident. A monitoring campaign conducted in eight village houses in August 2017 showed that
365 radioactive dose rates comprised between 0.15 and 0.4 $\mu\text{Sv h}^{-1}$ were found indoor on the floor, while
366 those measured nearby the ceiling varied between 0.2 and 0.8 $\mu\text{Sv h}^{-1}$. A previous campaign
367 conducted in 2014 showed significantly higher rates, reaching up to 2 $\mu\text{Sv h}^{-1}$. Whether this decrease
368 is sufficient to allow the return the population remains debated by several groups of experts (Itonaga,
369 2014a; Tsuda et al., 2017).

370

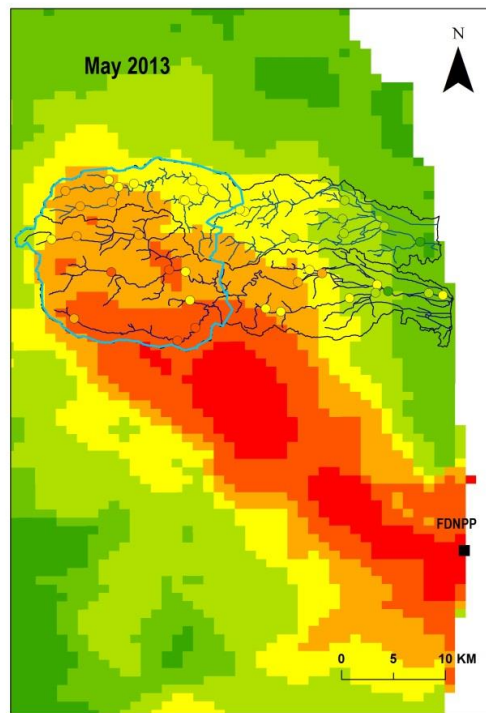
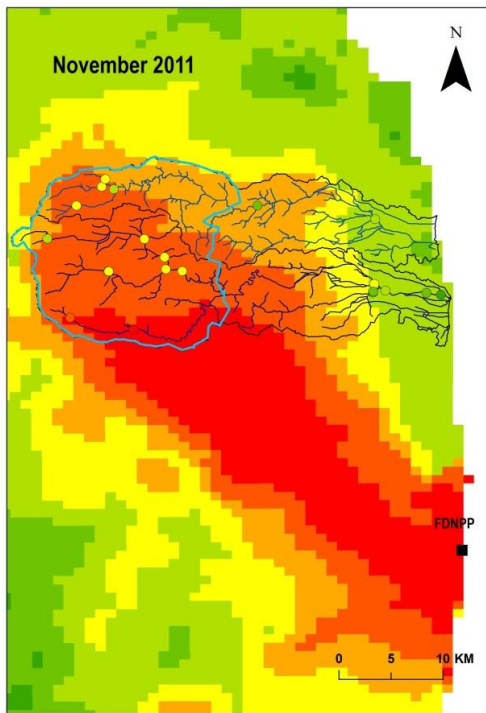
371 Furthermore, outside of the houses, the measured rates were higher than those measured indoor,
372 with a mean of 0.6 $\mu\text{Sv h}^{-1}$ at the ground level (Itonaga, 2014b). The houses surrounded by the forest
373 are exposed to the radiation of the woodland that could not be decontaminated, which is rather
374 paradoxical for people who lived in harmony with nature in a village such as Iitate. In June 2017,
375 measurements made on sap of the trees located nearby houses in Iitate showed that they contained
376 71.6 kBq kg^{-1} of ^{137}Cs in oaks and 19.6 kBq kg^{-1} in cherry trees. In the area monitored, some
377 estimations calculated that it will take a further 50 years before the mean radioactive dose rate drops
378 below 1 mSv.yr^{-1} (Itonaga, 2014a), which is the mean annual rate internationally recognized as
379 acceptable for the population in addition to the exposition to natural sources (ICRP, 2007). However,
380 this threshold was increased to 20 mSv yr^{-1} in the post-accident situation in the area located around

381 the FDNPP, in accordance with the recommendations made by ICRP (International Commission on
382 Radiological Protection).

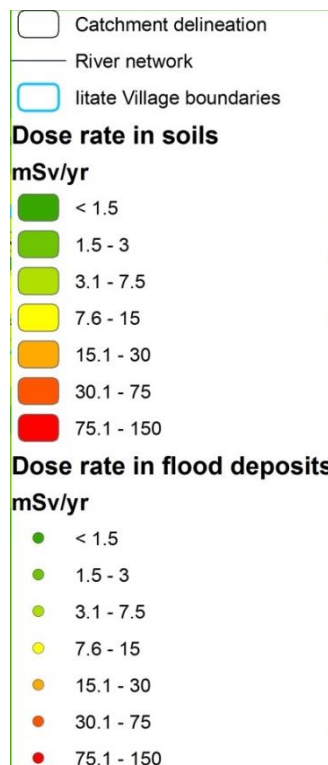
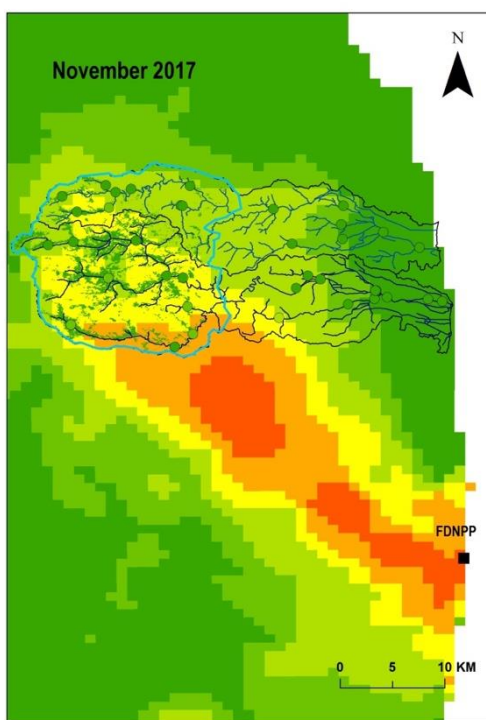
383

384 *3.6 Radionuclide redistribution in the landscape*

385 The frequent occurrence of heavy rainfall in the region leads to episodes of extensive soil erosion
386 and to the redistribution of sediment contaminated by radionuclides that strongly bind to soil
387 particles across the landscape, mainly through the river network (Chartin et al., 2017; Laceby et al.,
388 2016a). The radioactive contamination of the sediment transiting the Mano and Niida Rivers during
389 floods has been systematically monitored since the accident (Figure 5). The measurements clearly
390 showed that, despite variations in the contamination levels from one campaign to the next, a very
391 strong decrease (90%) of the ^{137}Cs levels was observed throughout time. In 2017, the radiation dose
392 rates emitted by the flood deposits in the river remained lower than 3 mSv yr^{-1} , while it exceeded 7.6
393 mSv yr^{-1} at most sites in 2011 and 2013. This very rapid and strong decrease is mainly attributed to
394 the export of contaminated material during typhoons (Nagao et al., 2014; Nagao et al., 2013) as well
395 as to the decontamination works (Evrard et al., 2016; Osawa et al., 2018). The effectiveness of the
396 clean-up efforts to decrease the contamination levels in the rivers is mainly explained because they
397 were concentrated on cropland and paddy fields that were shown to provide the main source
398 exposed to soil erosion in the region (Laceby et al., 2016b). In contrast, forests provide a lower
399 although continuous source of matter and radionuclides to the rivers (Huon et al., 2018), and the
400 difficulty to decontaminate forested areas will likely make them the main perennial source of
401 radioactivity to the rivers during the next several decades in this region. This different behaviour is
402 well illustrated on the map corresponding to the situation of November 2017 (Figure 5), with the
403 measurement of low radiation ($< 3 \text{ mSv yr}^{-1}$) in soils under decontaminated cropland and in inhabited
404 areas, although higher rates may be found in nearby forests (exceeding 15 mSv yr^{-1} in the southern
405 part of Iitate Village). This is likely one of the main reasons justifying the reluctance of many
406 inhabitants to return, as residential areas remain surrounded by contaminated forests, where no
407 remediation action is scheduled.



408



409

410 Figure 5. Evolution of radioactive dose rates measured in soils (background map) and in flood sediment deposits

411 (coloured dots) in the rivers of litate Village in November 2011, May 2013 and November 2017.

412 *3.7 The population's perception upon return*

413 A survey conducted by Professor Itonaga's team in December 2017 (Itonaga, 2018) among 52
414 households composed of 195 persons helped to identify the main trends regarding the inhabitants'
415 intentions upon their potential return to the village. Among the respondents, 11% planned to come
416 back to comply with the recommendation of the authorities, and 18% reported to be forced to return
417 because of financial difficulties associated with the subsidy removal. A further 20% of the interviewed
418 chose not to return despite financial problems, and 47% had not decided yet.

419 The residents who decided to return to their homes in Iitate (17 households) were also interviewed
420 on their residential options: 25% of them were able to renovate their house, 25% wanted to keep it
421 in its current state, and 12% did not plan to renovate it because of a lack of physical or financial
422 means. However, most buildings in Japan are constructed with natural and therefore perishable
423 materials (wood, straw, etc.) The subtropical climate to which Japan is exposed results in hot and
424 humid conditions in summer, which may significantly damage the buildings requiring frequent
425 renovations. Many of these buildings that remained vacant during seven years were in a dilapidated
426 state. Furthermore, the animals including wild boars, rodents and monkeys had reconquered these
427 inhabited areas. Accordingly, the households who did not plan to rehabilitate their house (37%) will
428 likely live in uncertain and unstable conditions.

429 The main reason (69%) why the inhabitants refused to return to the village is that they will not have
430 the opportunity to live with their children and grand-children anymore, as they do not plan to come
431 back. By July 2018, only 27 children (between 6 and 15 years of age) attended school in Iitate, while
432 they were ~400 children before the accident. In 2021, this number has fallen further to 23 pupils. The
433 town hall officers having children that were interviewed in the framework of the current research
434 did not live in the village and their children did not attend school in Iitate, which underlines the
435 complexity of the situation, including for the municipal officers. Many parents and grand-parents
436 underlined the difficulty to move children and force them to change to another school more than
437 seven years after they left the village. Furthermore, this trend, far from being reversed, has only
438 become more pronounced. The government offers financial support to those willing to develop a
439 business in the sector, but the incentives are clearly not considered to be sufficient.

440 A non-negligible proportion of villagers justified their decision not to return through the rejection of
441 living in a place where the mountains and the forests remain contaminated (64%). This is an
442 important point in a village where 74% of the surface area is occupied by forests. A similar percentage
443 of persons (65%) was reluctant to return because of the expansion of wild terrains and animals in the
444 village. Another problem was the lack of shops, health facilities and other infrastructures for 62% of
445 the respondents who decided not to come back. Furthermore, 53% of the people estimated that the
446 ambient radioactivity levels remained too high, 51% mentioned the difficulties to maintain an
447 agricultural activity and 51% were worried about the potential future health impacts of living in the
448 village. Among the interviewed who refused to return, a significant proportion of people (47%)
449 decided not to come back because of the because of the (contaminated) waste disposal frecon
450 bags strewn across the village. A considerable number of these bags have been removed to the
451 three storage centres near the power plant, but many of them were still many scattered across
452 agricultural landscapes. In 2022, 2.1 km² of land remained occupied by these big bags in the village
453 of Iitate (Fig. 2). Other minor reasons (mentioned by less than 40% of the respondents) for not
454 returning were the impossibility to consume mushrooms and other products from the mountains,
455 the absence of neighbours and the weakening of community relationships.

456 *3.8 Main reactions and difficulties of the refugees*

457 Several citizens defended their rights in court, like the family of Mr. Okubo, a 102-year-old man who
458 killed himself when he received the order to evacuate his hometown of Iitate. In February 2018,
459 the Fukushima District Court ordered the company that operated the FDNPP (Tokyo Electric Power
460 Company Holdings Inc.), to pay compensation for the pain caused by this suicide. Other villagers
461 organized themselves in associations (e.g. *Iitate Network*, *Resurrection of Fukushima*) to measure the
462 radioactivity in the environment surrounding them or to provide services and assistance to the
463 community. During the evacuation, they rented fields in the vicinity of their temporary buildings to
464 maintain collective agricultural activities.

465

466 Among the refugees interviewed, many mentioned the impossibility for them to move to another
467 village in the countryside. Those who were born in Iitate know “where the water flows and where
468 the wind blows”. Often, the husband native of Iitate convinced his wife to return to the village. “The
469 most difficult is not to be able to touch the vegetation around” said the wife of a farmer, native from
470 Nihonmatsu, who followed her husband when returning to Iitate although she would have preferred
471 to continue living elsewhere.

472 Despite the difficulties to restart those economic activities related to the exploitation of land and
473 forest resources, several inhabitants came up with original solutions. Collective greenhouses were
474 installed, with soil imported from the Fukushima City with “only 100 Bq kg⁻¹ of ¹³⁷Cs” to cultivate safe
475 leaf vegetables. In experimental fields, the cultivation of tobacco or sorghum is tested. The cultivation
476 of flowers – and those from Iitate were formerly renowned in the entire region – is also envisaged,
477 as “we do not eat flowers” said a farmer who has now retired. Restarting an activity is easier for those
478 few people working in the economic sectors that do not necessarily directly depend on the local land
479 resources, like that family that reopened a noodle (*udon*) restaurant, the village’s only restaurant in
480 2018.

481 Practical difficulties are also associated with the old age of those people who returned, who fear to
482 lose their mobility when they will not be able to drive anymore. The previous staff refused to return
483 to work at the only retirement home of the village (*Iitate Home*), and medical consultations are only
484 possible at a dispensary during a few hours two days per week. The previous villagers of Iitate are
485 often stigmatized by other citizens, as they are supposed to “have received plenty of public money
486 without doing anything”. However, as a resident who returned to the village mentioned, “living in a
487 safe landscape cannot be bought with money”.

488

489 *3.9 Main reactions of the municipality*

490 The village hall officers are confronted by the accelerating age profile of the resident population.
491 Although ~3000 persons commuted every day to work in Iitate by July 2018, almost all the 750
492 inhabitants who stayed day and night in the village were older than 65. Most farmers sold their

493 agricultural equipment and many of them were too old and did not have the physical means anymore
494 to maintain their diverse farming activities associating cultivation and cattle breeding. Some
495 landlords devoted their fields to the installation of solar panels (Fig. 2) with the authorization of the
496 village hall to convert land to this end. Others have rented their land to the municipality for the same
497 use as Mr Masao Uchibori, the governor of Fukushima Prefecture is focused on making it [green]
498 energy self-sufficient by 2028 so solar panels are very popular in the area and an increasing
499 surface area is devoted to them. In 2022, 0.9 km² of land in Iitate was covered by solar panels.
500 However, the municipality does not want to further extent the surface covered with solar panels and
501 would like to achieve the recovery of farming activities in Iitate instead, with the support of the
502 agricultural municipal department.

503 Before the accident, the budget of the municipality was 36 million USD. To support the reopening of
504 the village, the Japanese central government attributed an additional budget of 180 million USD to
505 the municipality in 2017, and 90 million in 2018. This likely demonstrates the major role played by
506 Mr. Norio Kanno, who has been the mayor of the village for two decades, for reopening the village
507 to the inhabitants. The local authorities mainly spent the budget granted by the Japanese
508 government through the renovation of the village party hall that may accommodate more than 200
509 guests, the construction of a new town hall building to accommodate the municipal services, multi-
510 sport competition areas, a new school and a shopping mall (*madeikan*) where local food products
511 and necessities can be bought. Until 2022 a device was also available to measure the radioactivity in
512 food products. Two convenience stores reopened in the village, even if they close early on evenings.
513 One of them had to close due to lack of customers. Indeed, despite these massive public investments,
514 very few economic activities had restarted in the village by 2022 and the population is declining
515 despite government proposals to fund people to repopulate the area. Only 192 individuals (or 97
516 households) responded to this call in January 2022.

517 **Conclusions**

518 Despite the significant decrease of radioactive dose rates in soils, vegetation and rivers observed
519 between 2011 and 2017, radionuclides in general, and radiocesium in particular, are still found in
520 some parts of the environment of Iitate. In addition, the residents were suddenly confronted with a

521 situation that was truly unknown to them until 2011. They are either on the lookout of the slightest
522 Becquerel or, on the contrary, they do not want to hear about it anymore. It is difficult for them to
523 know on which values to rely, in a context where the rules and the thresholds have been revised
524 several times. Furthermore, despite the considerable financial effort to decontaminate the cultivated
525 land and rebuild the municipal infrastructures, the resumption of economic activities remains a real
526 challenge as the village strongly relied on its natural resources with the dominance of those activities
527 associated with agriculture and forestry before the accident. The lifting of the evacuation order in
528 the contaminated areas of the Fukushima Prefecture threw the population in great disarray. The
529 inhabitants had been confronted to difficult choices during the last 10 years. This excessive stress
530 that sometimes led people to commit suicide may be attributed to the difficulties associated with
531 the prolonged life in temporary housing facilities, to the enforced nature of the return, or the
532 disillusionment following the resettlement. Those families who lived with three generations under
533 the same roof, with the younger taking care of their elderly parents, were dislocated, and the elder
534 are often actually left alone without family or close neighbor. There is no evidence of a mass return
535 of refugees to their home villages, despite the cutting of shelter subsidies and payment for return.
536 These measures do not seem to provide sufficient incentives to boost the repopulation of the region.
537 The current development does not seem to show any drastic growth. Five years after the reopening
538 of the village, less than 20% of the population has returned, which does not appear very promising
539 less than one year before the planned reopening of the difficult-to-return zone. The interdisciplinary
540 analysis of this case study allows us to highlight the complexity of the obstacles encountered by a
541 reopening policy that advocates a tendency to learn how to "live with radioactivity" by only
542 responding point by point to the individual problems encountered without considering the whole
543 picture. Furthermore, the decontamination of the cultivated land, while allowing most returnees to
544 restart their activity, will not allow them to exploit and enjoy the forests as they did before, as they
545 still represent a potential perennial source of radioactive contamination for the years to come.

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