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Rain-enhanced/induced bioecological resuspension of radiocaesium in a polluted forest in Fukushima

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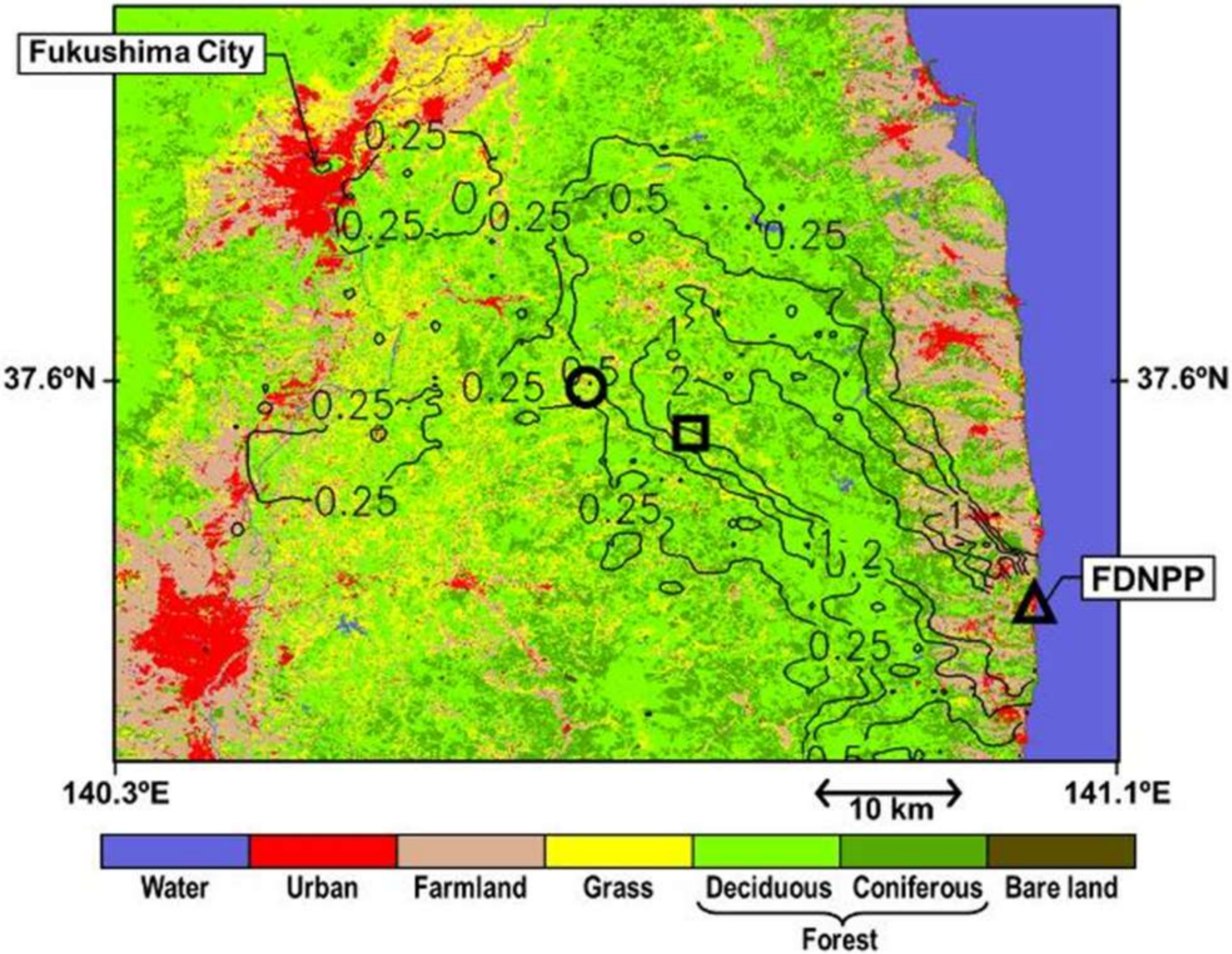
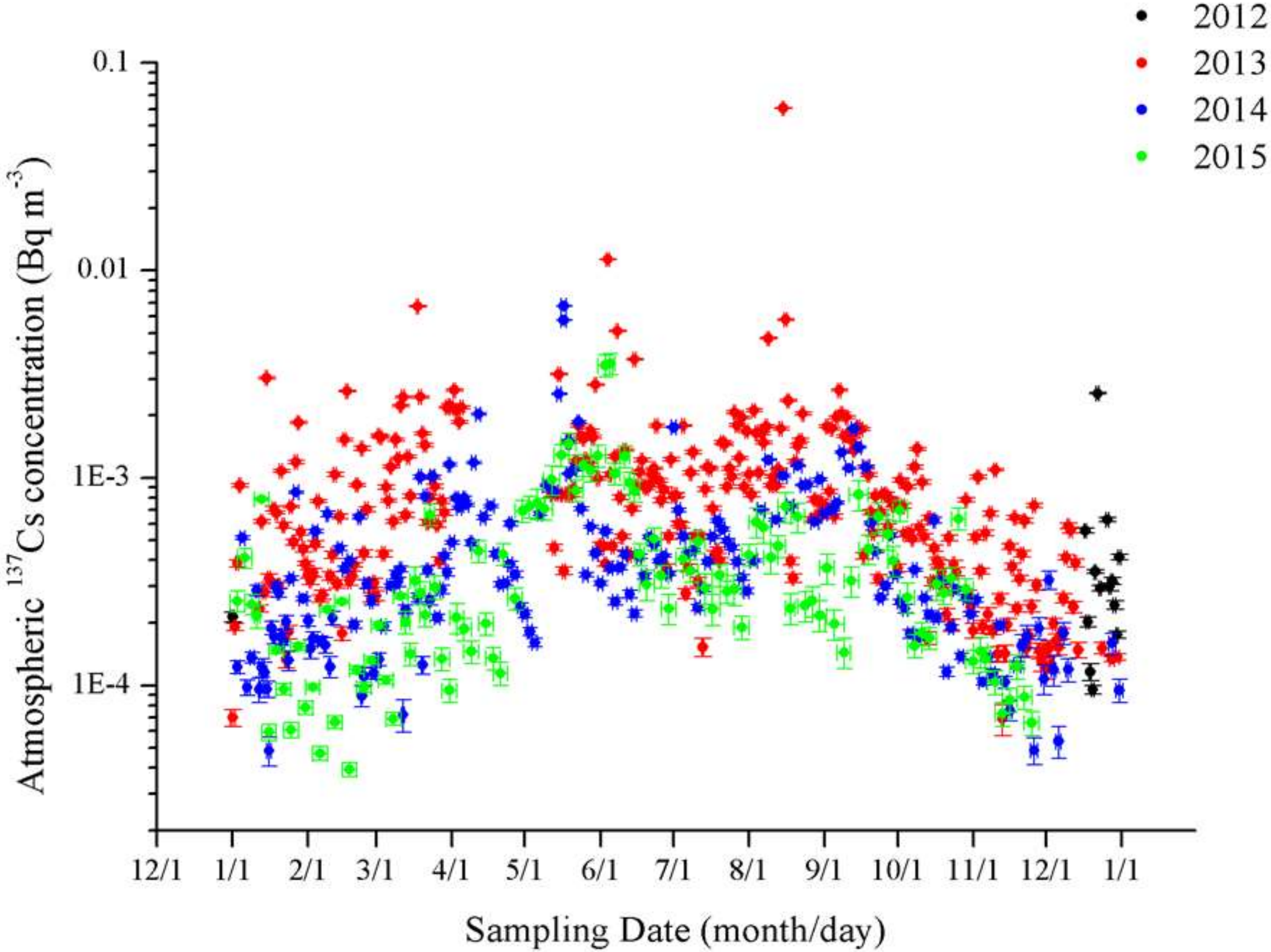


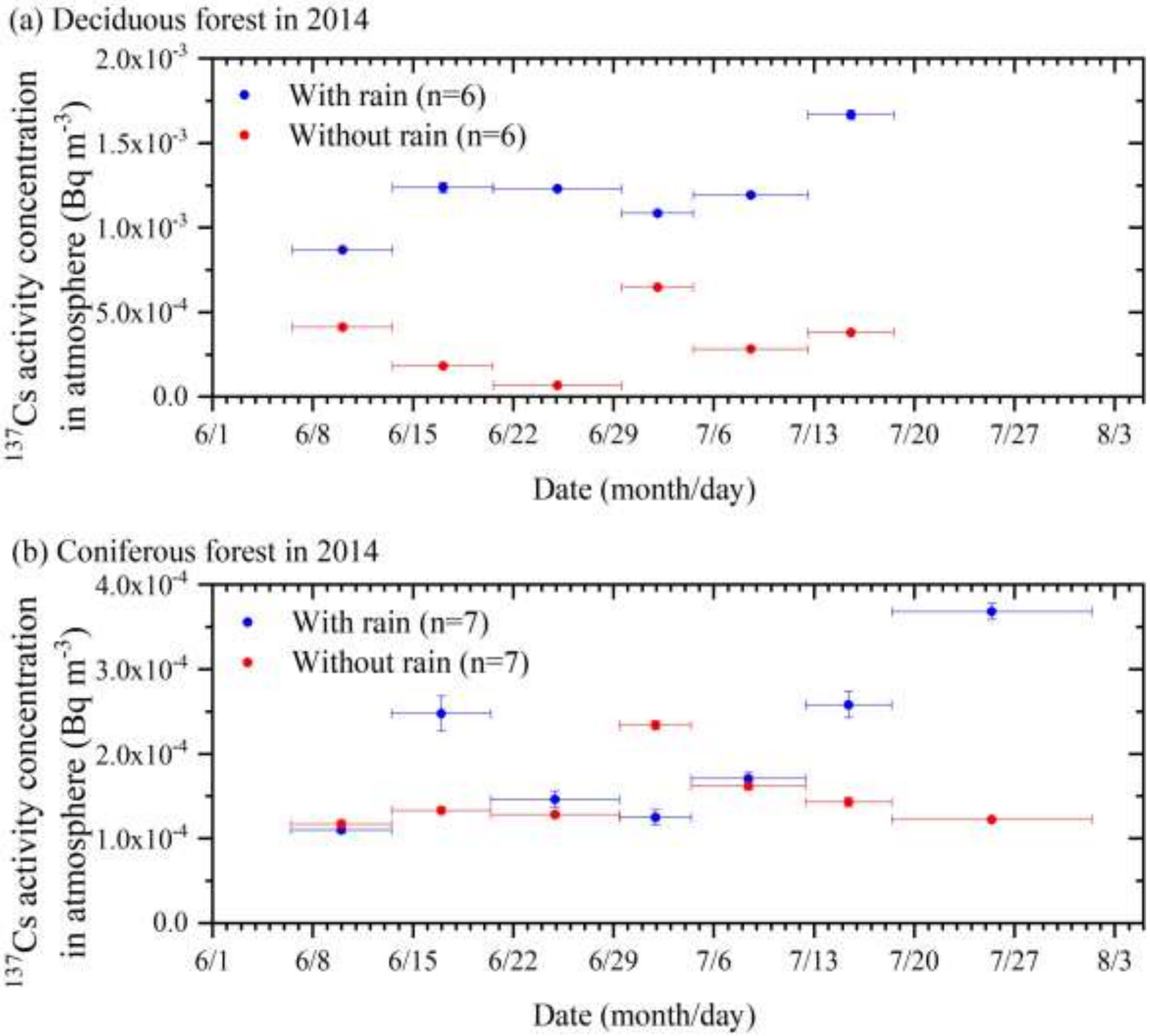
Observation site locations along with a land-cover map of the eastern part of Fukushima Prefecture before the F1NPP accident. Triangle, FDNPP (F1NPP); circle, Kawamata site; square, Namie site. The map was created by using data from the High-Resolution Land Use and Land Cover map published by the Japan Aerospace Exploration Agency Earth Observation Research Center ALOS/ALOS-2 Science Project and the Earth Observation Priority Research: Ecosystem Research Group. The contour line shows the deposition density of ^{137}Cs originating from the F1NPP accident ($MBq\ m^{-2}$) at the end of May 2012. Permission to use the data was granted. Deciduous forest is a mixture of various broadleaved trees, excluding evergreens. Coniferous forest excludes deciduous needleleaved trees, which are rare in the region.

Kita, Igarashi, Kinase, Hayashi, Ishizuka, Adachi, Koitabashi, Sekiyama & Onda, Scientific Reports, in review.



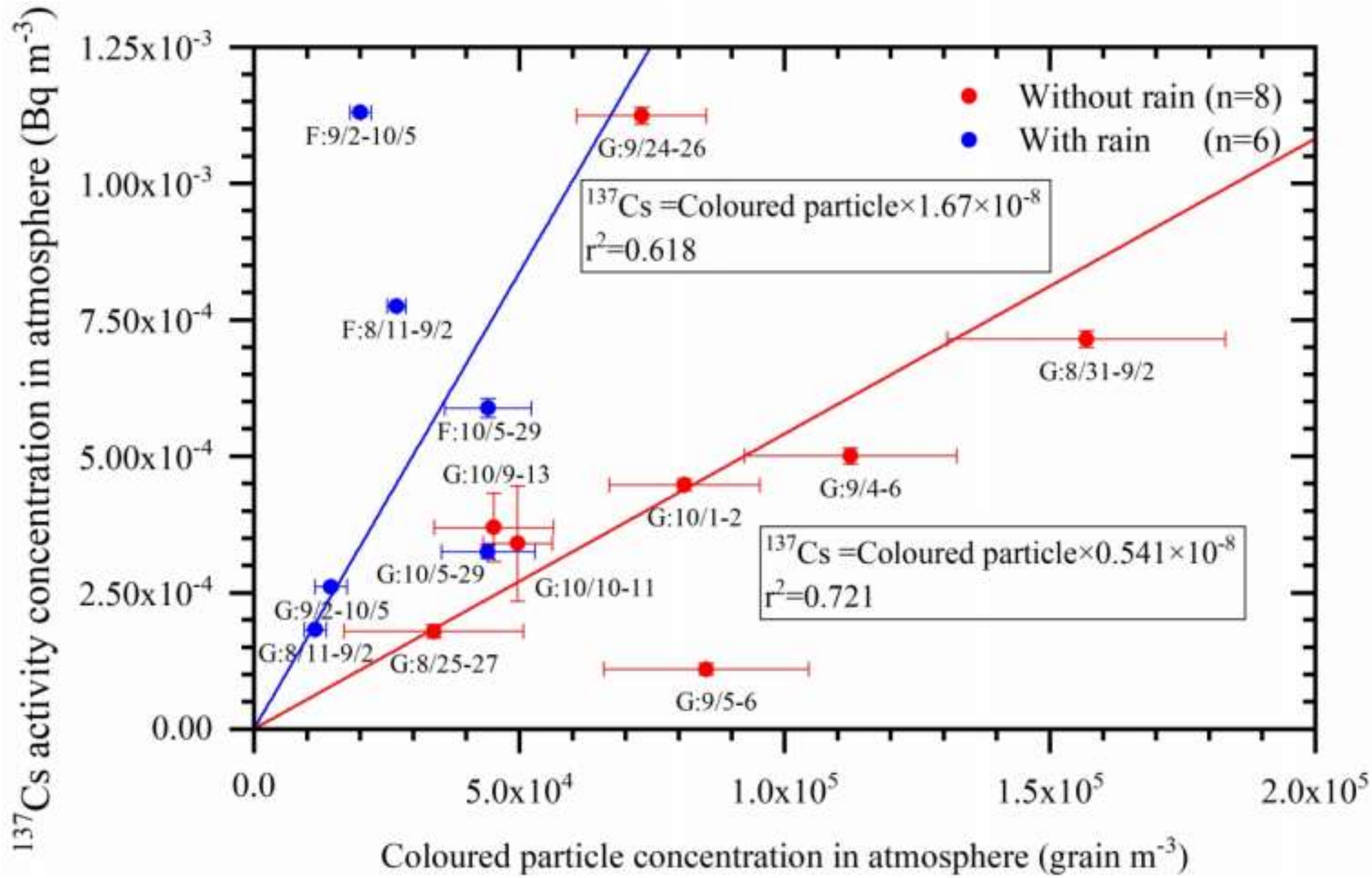
Temporal changes in atmospheric ^{137}Cs concentrations observed at Namie in Fukushima Prefecture from 2012–2015 showing seasonal variations. Horizontal and vertical bars for each value represent the sampling duration and measurement errors, respectively.

Igarashi, Y., Kita, K., Maki, T. et al. Sci Rep 9, 1954, 2019. https://doi.org/10.1038/s41598-018-37698-x



Atmospheric ^{137}Cs concentration inside the contaminated forest in Fukushima Prefecture, Japan, during the summer of 2014.
The rainy/nonrainy sampling was carried out from June 6 to August 2, 2014. The sampling period was shorter in the deciduous forest than in the coniferous forest. Samples collected during rain periods are shown in blue, whereas those collected during periods without rain are shown in red. Horizontal error bars indicate the whole duration of the sampling, while the vertical bars exhibit errors in the activity measurement. The top (a) and bottom (b) panels show the data from the broadleaf and coniferous forests, respectively. In the broadleaf forest, ^{137}Cs concentrations are always higher during the rainy period than during the nonrainy period. On the other hand, in the coniferous forest, ^{137}Cs concentrations tended to be higher than those during the nonrainy period, except in late June to early July.

Kita, Igarashi, Kinase, Hayashi, Ishizuka, Adachi, Koitabashi, Sekiyama & Onda, Scientific Reports, in review.



Relationship between the coloured fungal particle number concentration and ^{137}Cs activity concentration in the air at the Namie site (inside the forest (F) and the bare ground (G)) during warm seasons in 2016.

Sampling dates are expressed as mm/dd (e.g., m1/d1-m2/d2). Six of the present plotted data for nonrainy period, that had been published in Igarashi et al. (2019) were reevaluated using the present spore counting method. The collection duration for nonrainy samples was 24 hours in the daytime or nighttime (G:8/31-9/2, G:9/4-6 and G:9/24-26) of the dates shown next to each data point. For instance, daytime data of G:10/1-2 indicates that the sampling was performed from 6:00 to 18:00 on October 1 and October 2 for a total of 24 hours. On the other hand, the collection duration for rainy samples encompassed several weeks due to the small percentage of the whole sampling period represented by rain. Here, regression curves were obtained by assuming that ^{137}Cs was carried only by fungal spores; thus, the curves should pass the origin.

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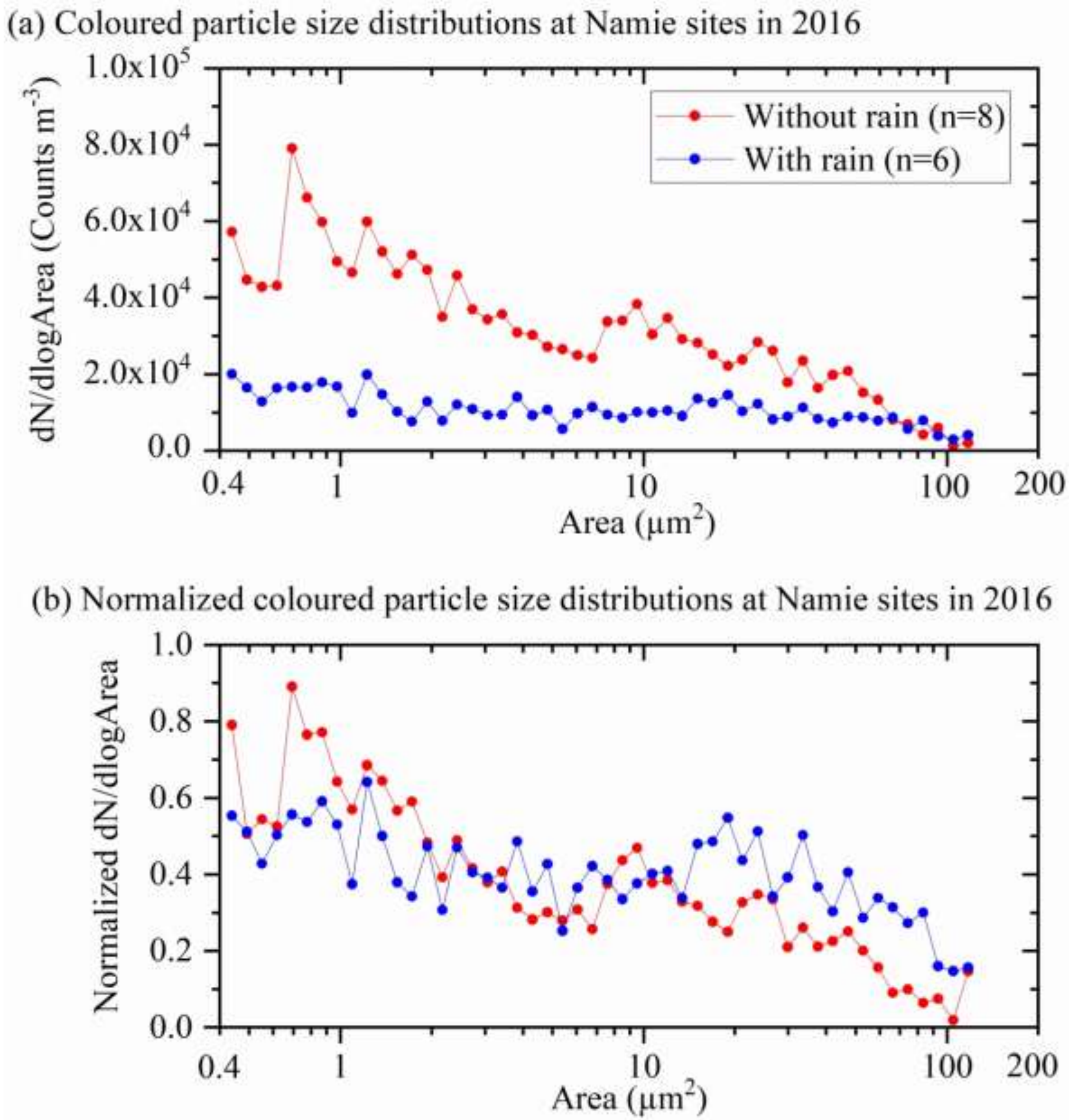

Averaged (number concentrations per unit air volume (Y)) (a) and normalized (dividing by the sum of the total number (Y)) size distributions of fungal particles (b) collected on the HV filters (n=6 and 8 for rain and nonrain, respectively) obtained in 2016 using image analysis software.

The bin size of the horizontal axis (X; dlog Area) is 0.1 on the scale of the base 10 logarithm. Analysed optical microscopic images were taken from the same filter samples as those shown in the previous figure. The size of each fungal particle is expressed in terms of the projected area. One pixel corresponds to approximately 0.008 μm^2. Particles beyond the size of approximately 120 μm^2 (more than 15000 pixels) were cut-off to avoid overlapping images of particles. The size distribution shifted towards larger sizes with rain than without rain. (a) and (b) reveal that the total number concentrations of coloured fungal spores decreased during rainy periods compared to during nonrainy periods (0.34) and that the portion of large spores (beyond approximately 15 μm^2) was higher during rainy periods than during nonrainy periods.

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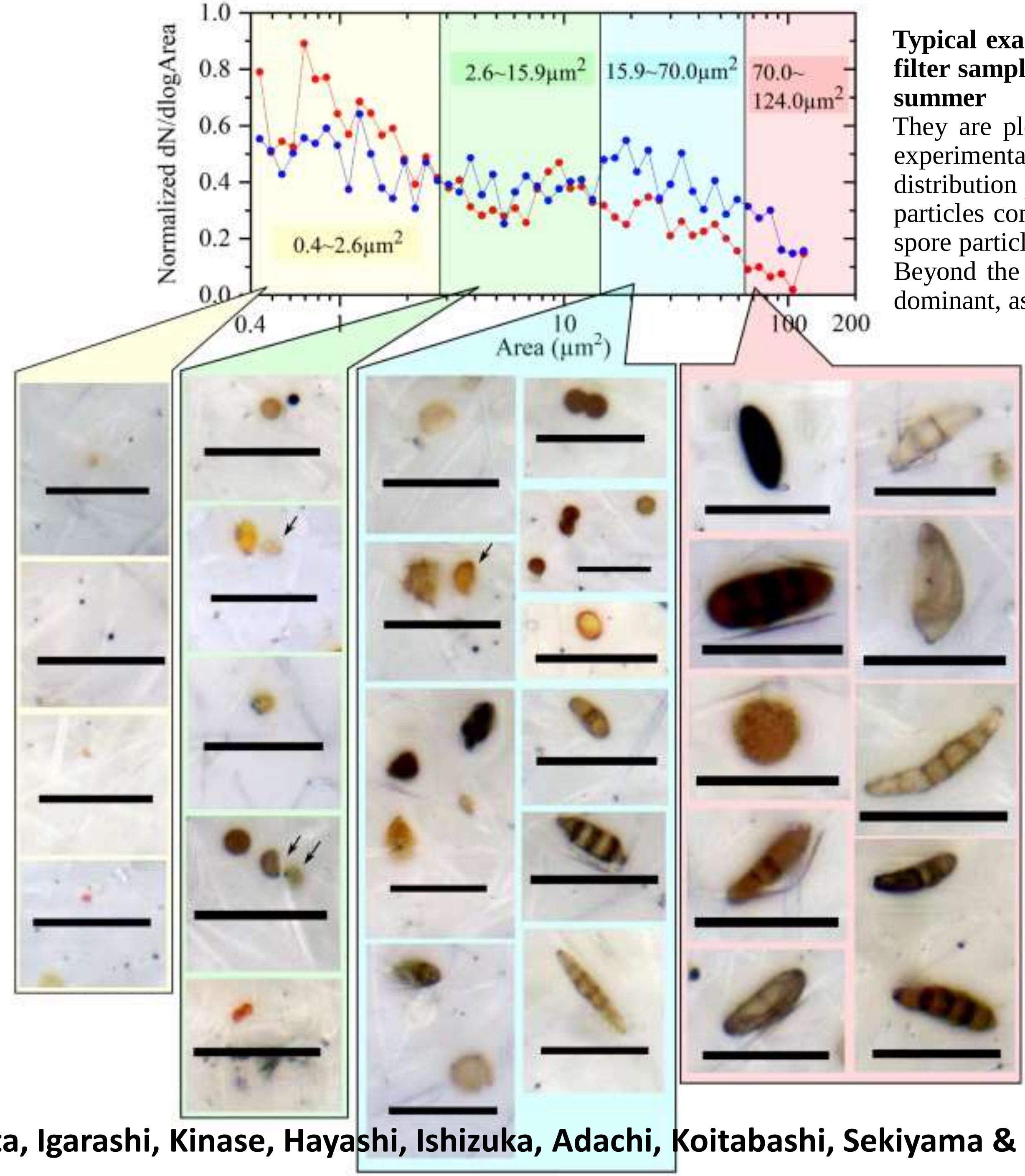

Typical examples of fungal spore particles on the HV filter samples taken at the Namie site during the 2016 summer

They are plotted along 4 projection size bins based on experimental/convenient classification. The size distribution plot is from Figure 5 (b). Arrows indicate the particles concerned, and the bar length is 20 μm. Fungal spore particles are sorted according to the projection area. Beyond the 15 μm^2 range, conidia and ascospores were dominant, as shown in this figure.

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Summaries

- We show additional evidence for rain-induced aerosol emissions in a forest environment: the occurrence of radioCs-bearing aerosols in a Japanese forest due to rain.
- Rrain induces/enhances the release of approximately 2 times as much radioCs-bearing coarse bioaerosols (especially with a projection size of >15 μm^2) into the air in a polluted temperate forest range, although the total number concentration of bioaerosols is reduced to about 1/3 under rainy conditions.
- Conidia and ascospore particles may represent the coarse bioaerosol particles based on the analysis of size and morphology. Therefore, one of the mechanisms behind the summer maxima in radioCs over the polluted fores was revealed to be rain splash.
- The finding has many implications for forest ecology, meteorology, climate, public health, agriculture, and other research fields in which fungal spores play significant roles.
- However, there are limitations to the present study; we investigated the increase in bioaerosols on the basis of only radiocaesium and coloured spores, while other bioaerosol components such as organics (mannitol,) were not studied in detail.