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INSTITUT
DE RADIOPROTECTION
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Faire avancer la sûreté nucléaire

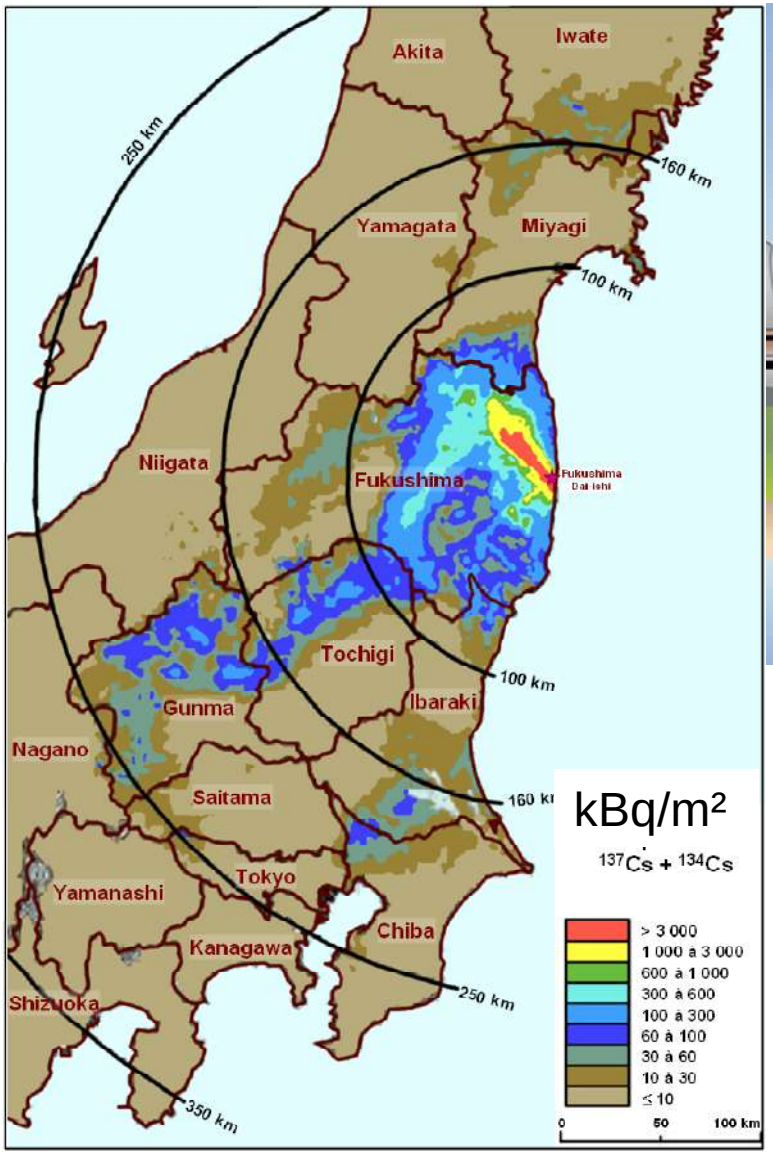
Contamination of the Japanese environment after the Fukushima accident and associated doses to the population

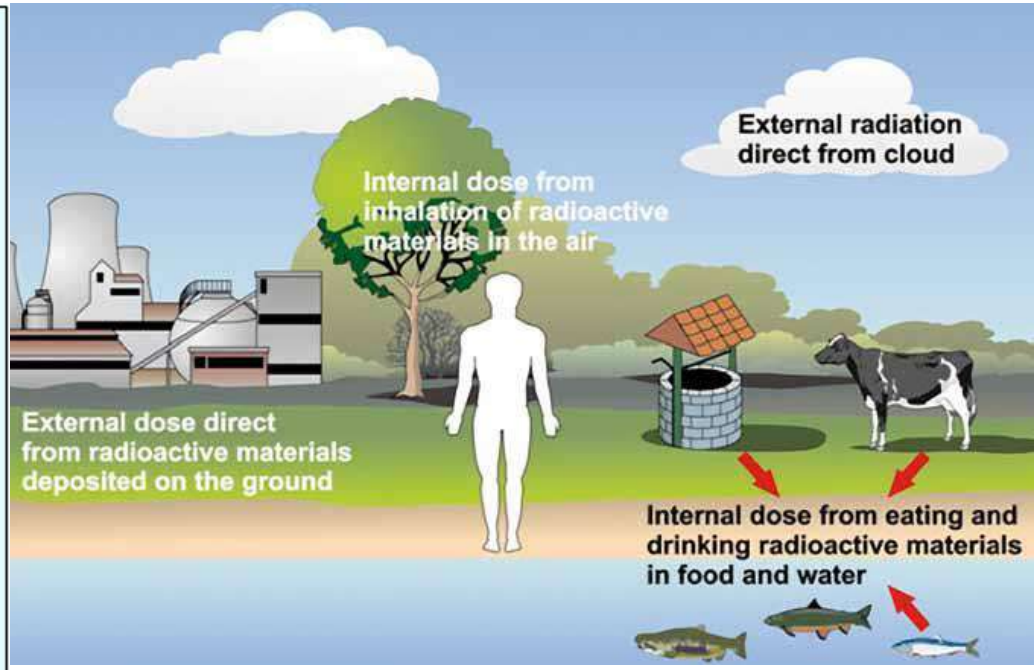
M. Simon-Cornu & P. Renaud

Winter-school EURADOS

Milano February 11, 2016

At the origine of the consequences of the Fukushima accident were the radioactive deposits





Source: WHO Fukushima report, reproduced from IAEA Chernobyl report

1 000 000 Bq/m² (radiocésium) → 2 - 4µSv/h

Source: MEXT

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Part 1:

Foodstuff contamination and associated doses

Elements relative to foodstuffs contamination after an accidental deposit

The most contaminated agricultural produce after an accidental radioactive deposition are those during cultivation or those the harvest of which is imminent (days to weeks depending on the type of production)

Leaves are needed for the interception of deposits and a minimal growth-stage is also necessary for the transfer from leaves to edible part of the plant (fruit, grain, root…). This growth-stage is reached between mid-spring and summer for most of cultures. And even in this case, only a small part is transferred.

Leafy-vegetables for which leaves are the edible part (salad, spinach, leek, cabbage…) in cultivation at the time of deposits are then potentially the most contaminated foodstuffs. Highest activity levels are reached immediately after the deposits. The plant growth leads then to a quick decrease of their massic activity (dilution)

The root-transfer is very small, even negligible in relation to the foliar-transfer, but long-lasting, decreasing slowly but faster than radioactive decay

Contamination of animal products is directly linked to that of their food

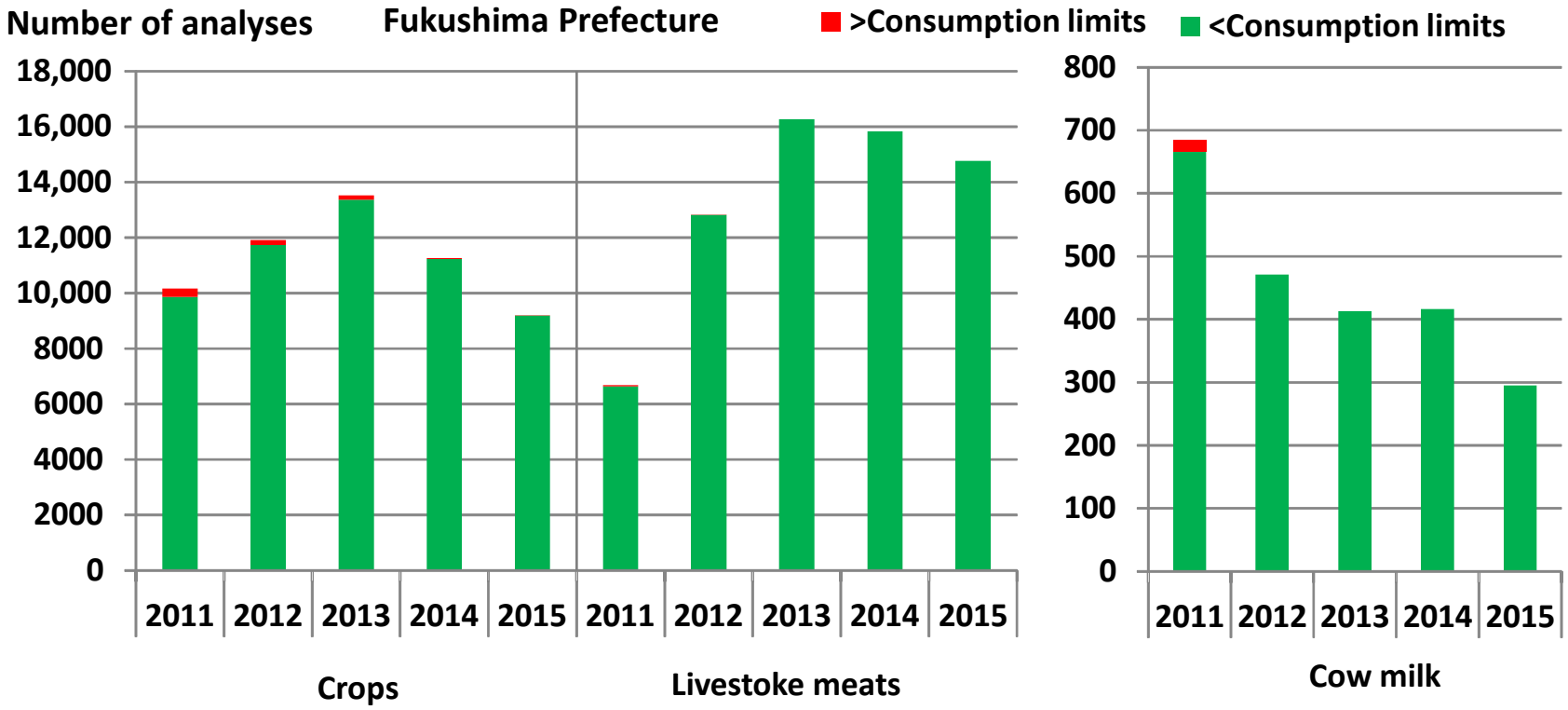
The agro-climatic context in March 2011 in Japan

- An end of Winter in a temperate zone ; snowy-rain during the radioactive deposits
- Vegetables (and few strawberry) are the only crops in growing, under greenhouse notably
- Except some japanese apricot, fruit-trees have neither leaves nor flowers
- Some cereals are installed but are far from the flowering (in May)
- Some semi-natural vegetals and some specific shrub have their leaves (bamboo-trees, tea-trees, aralia…)
- The most common feeding pratice for lifestock is based on importing fodder


Kawamata valley on early April

In March 2011, leafy-vegetebles, notably spinach, are by far, the most contaminated foodstuffs

Contamination of foodstuffs from the Fukushima prefecture

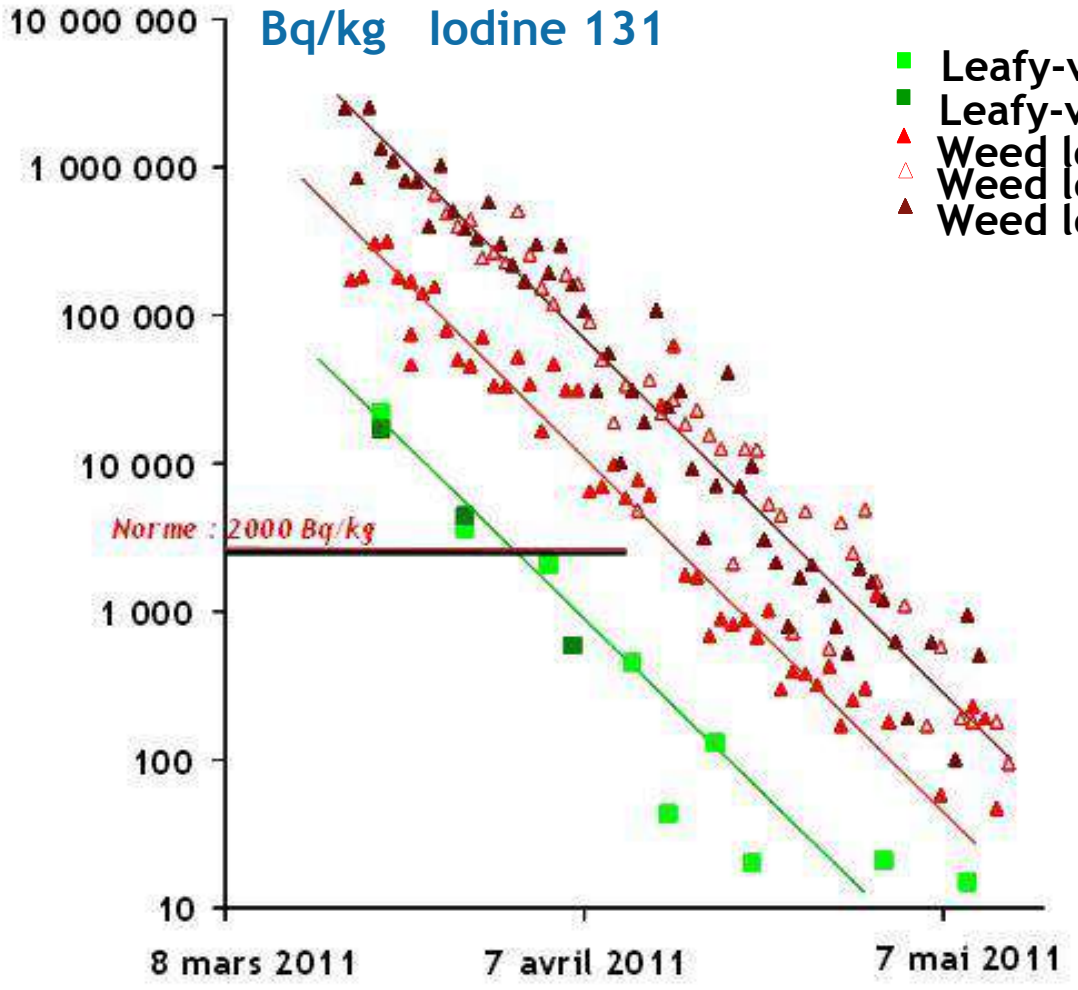


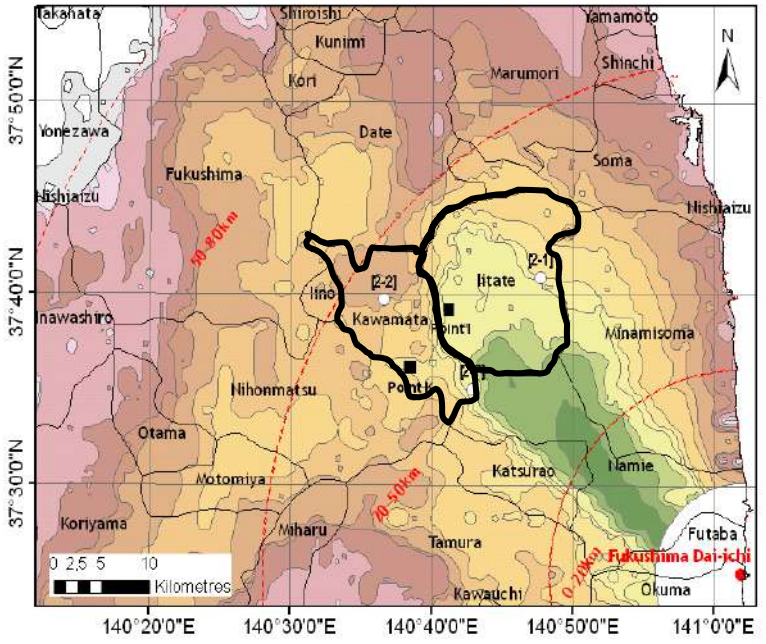
Number of analyses of foodstuffs from the Fukushima Prefecture with measured activity above (respectively below) the consumption limits (CL) : 2000 Bq/kg for ^{131}I ; 500 Bq/kg until March 2012, and 100 Bq/kg since then for both cesiums.

Due to the season of the accident (winter) and to the importation of fodder (and the control of their activity), crops and livestock products from the Fukushima Prefecture have remained overwhelmingly below the consumption limits (CL), even in 2011

Iodine-131 fate in weeds and leafy-vegetables

Decrease of activities for iodine 131 due to radioactive decay (half-life: 8 days)+ other environmental processes => vanishing of iodine 131 after May 2011





Activities of Milk *vs* Weed

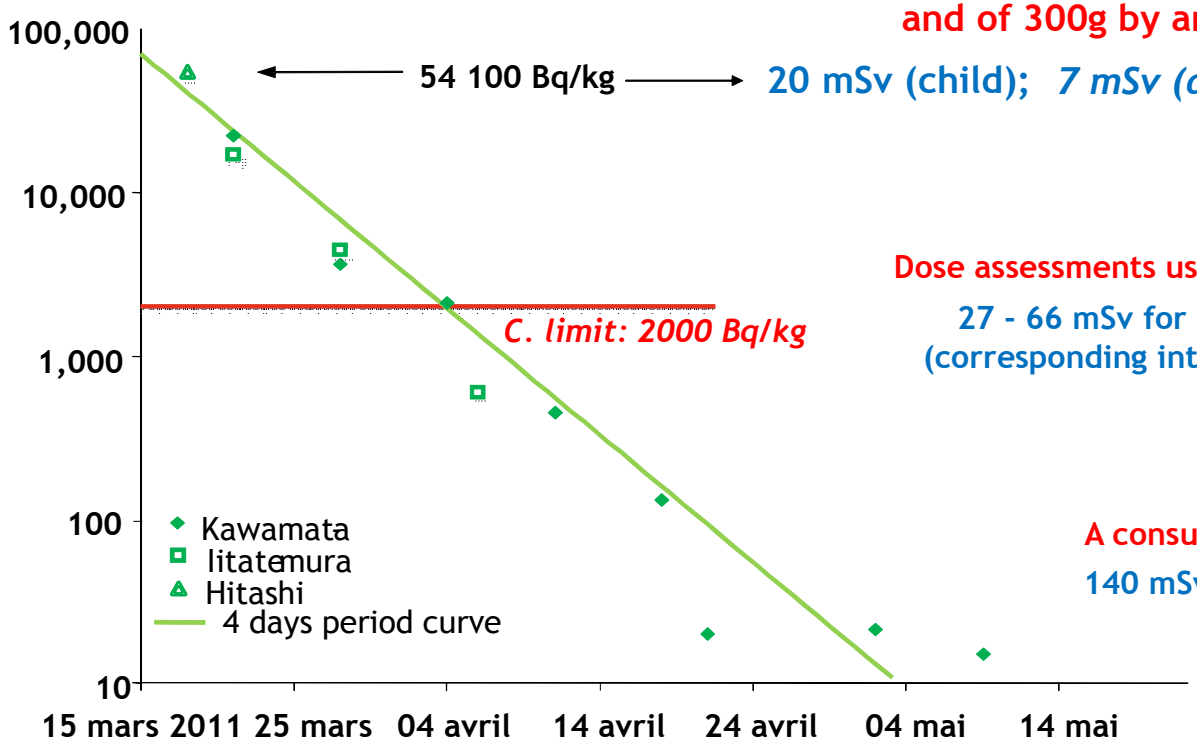
Equivalent dose to thyroid for non-evacuated persons

UNSCEAR assessment: adult : 8 – 17 mSv ; 1 year old child: 33 – 52 mSv
(all pathways)

Thyroid activity measurements show doses 3 to 5 times lower

Doses quicky reached by the ingestion pathway

^{131}I in leafy-vegetables (Bq/kg)



Thyroid dose due to a consumption of 100g by a 1 year-old child and of 300g by an adult

20 mSv (child); *7 mSv (adult)*

Dose assessments using urine analysis

27 - 66 mSv for 5 adults and a 14 year-old child
(corresponding intake of few kg of leafy-vegetables)

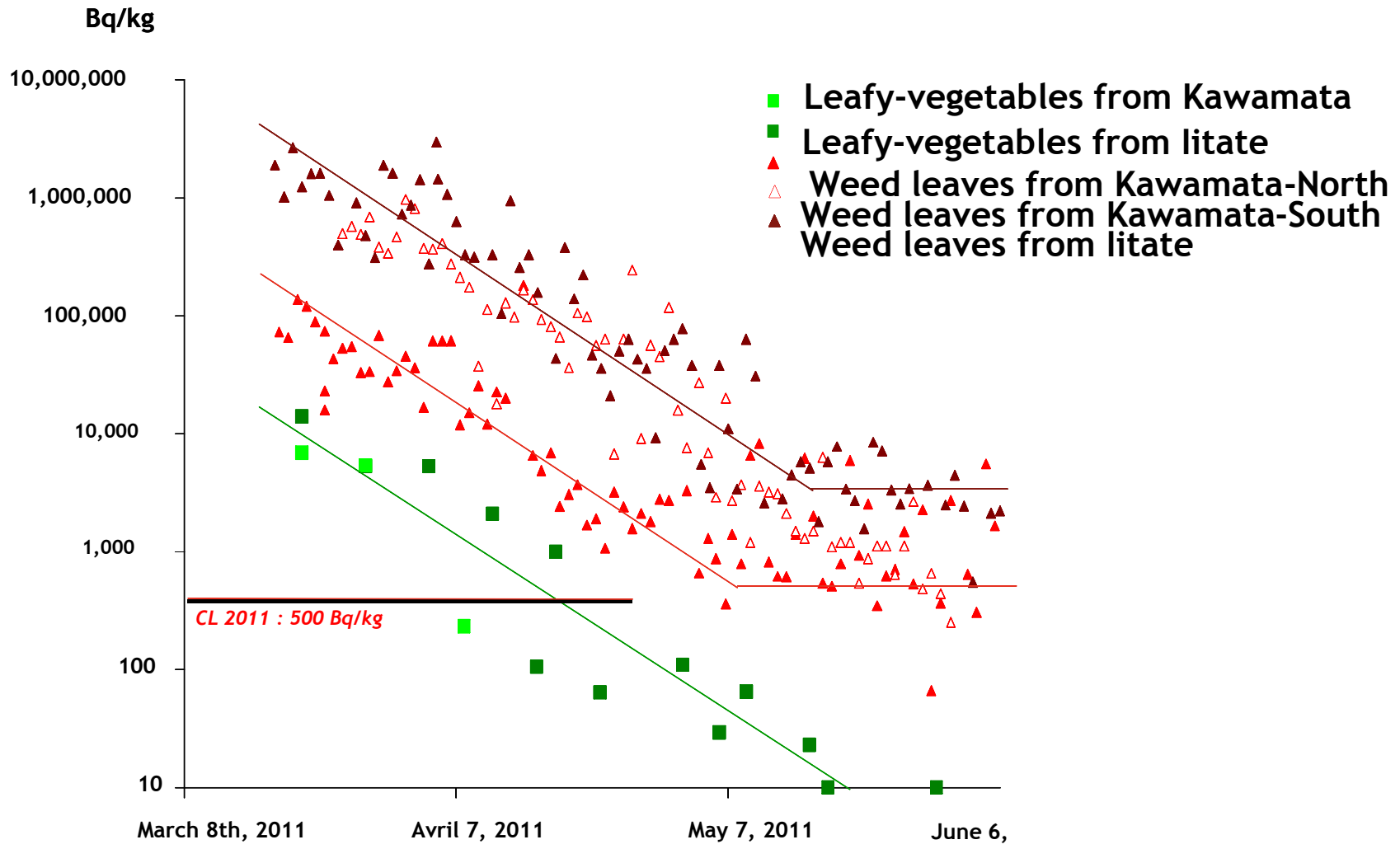
A consumption during 1 month

140 mSv (child) *50 mSv (adult)*

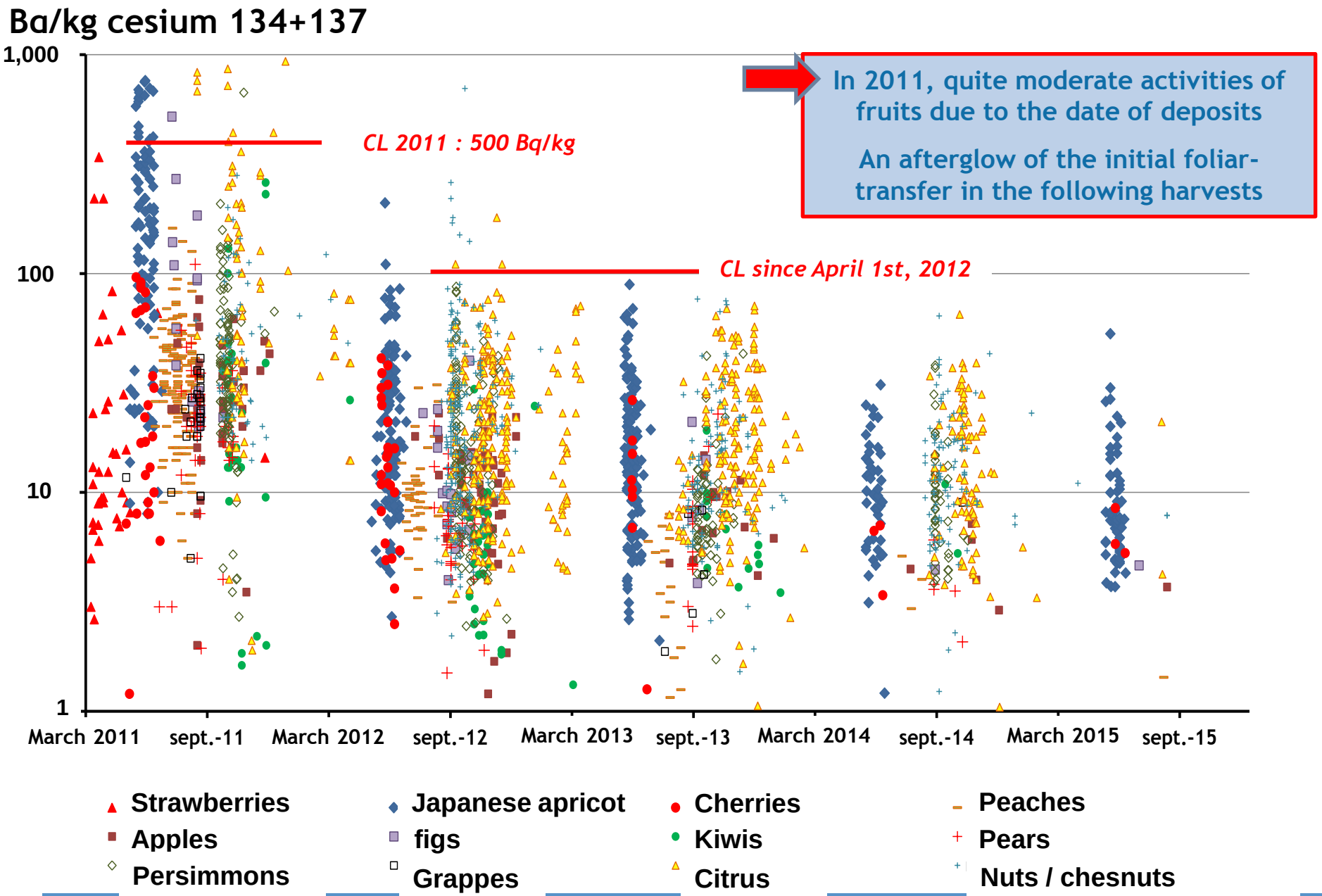
Fate of Cesium in weeds and leafy-vegetables

Bq/kg Cesium 137+134

Decrease of activities of about a factor 100 to 1000 in 3 months for cesium



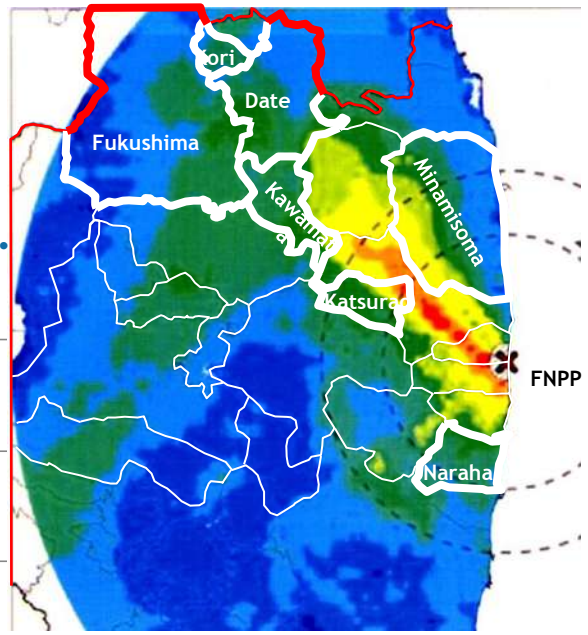
Fruits activities

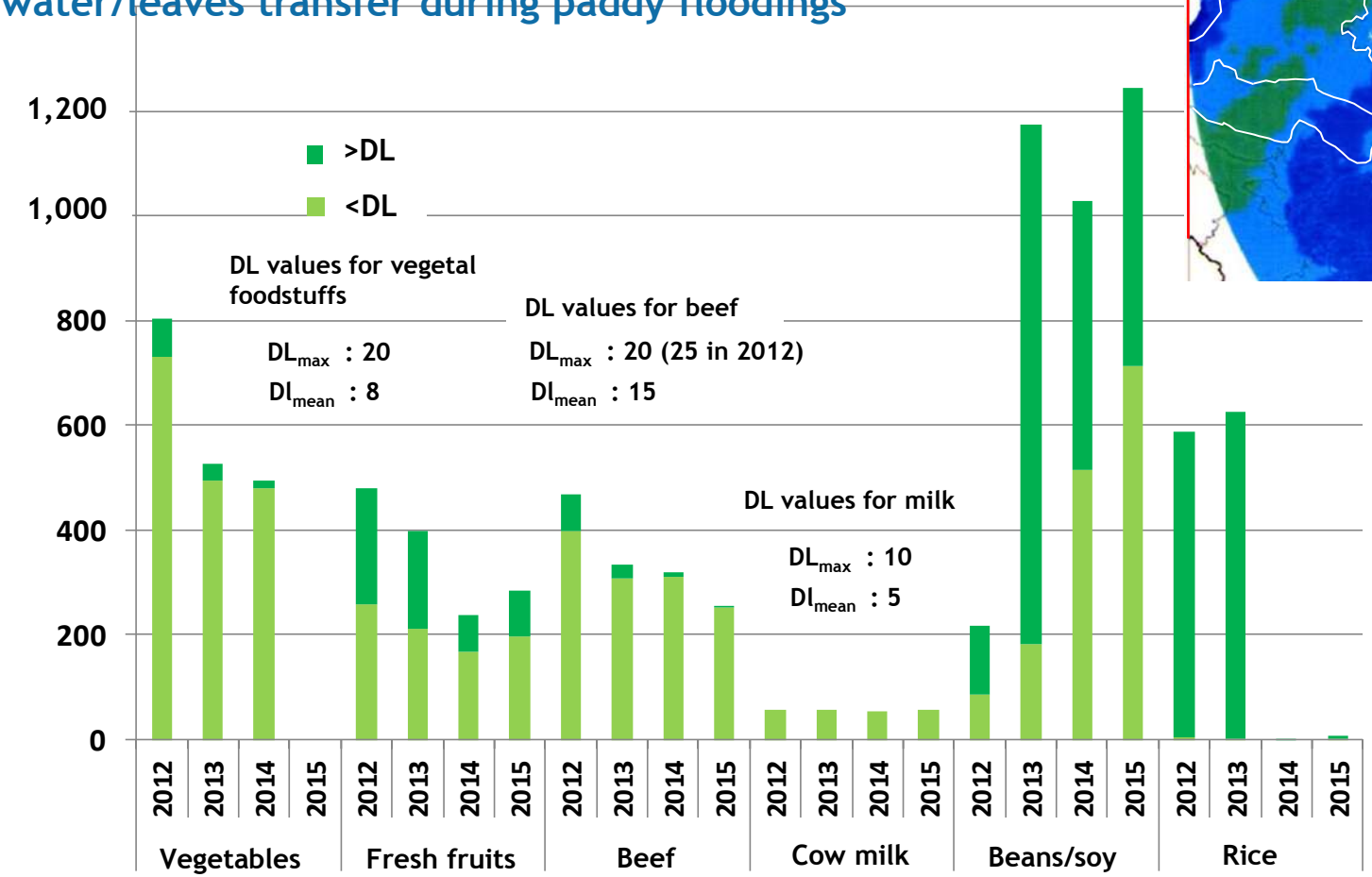


Activities of foodstuffs from most contaminated but non-evacuated localities (2012-2014)

Activities of vegetables and livestocks products are overwhelmingly below detection limits (DL) which are 5 to 10 times below consumptions limits

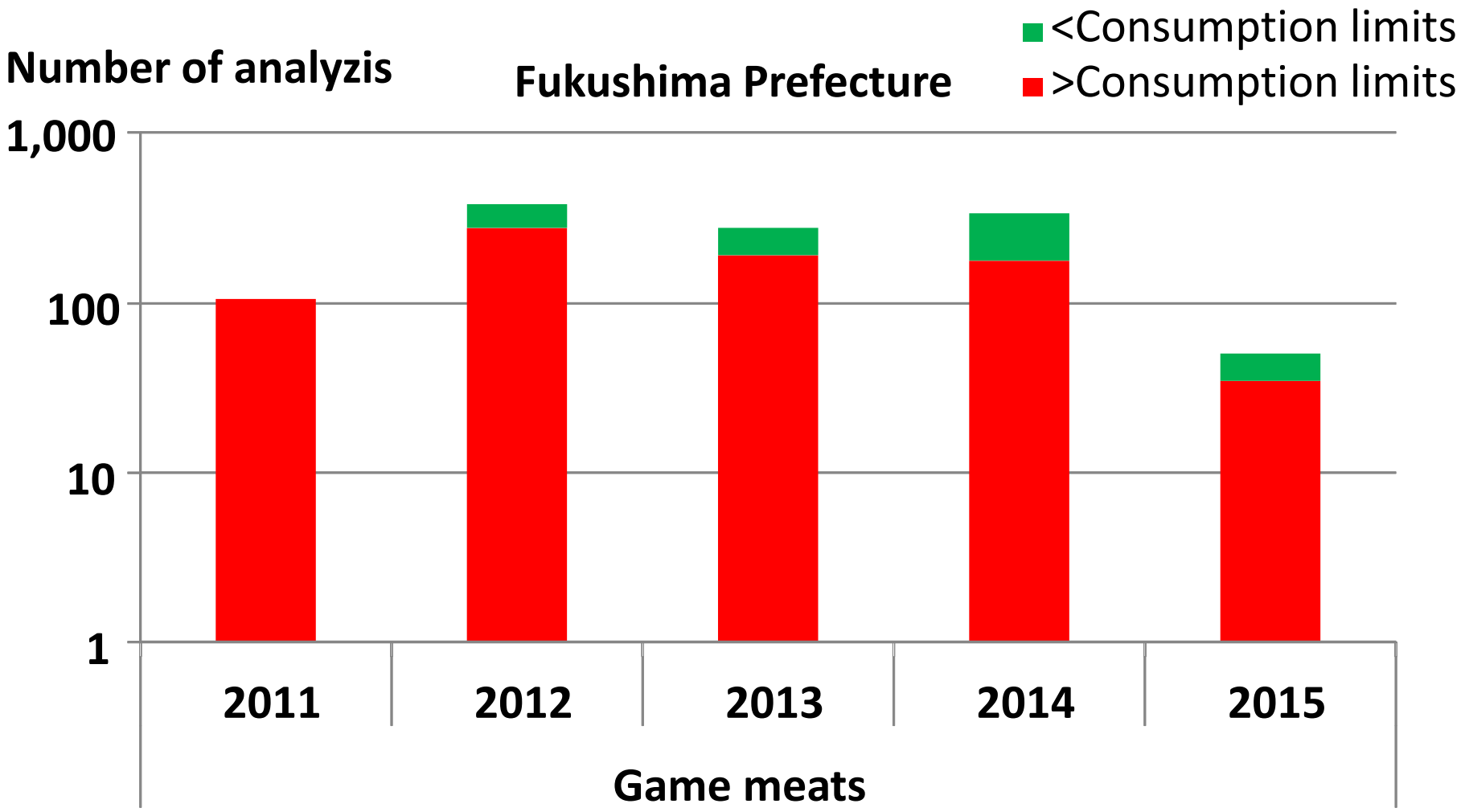
Bean species (notably soy) and rice are above detection limits. Due to a higher root-transfer (for beans) and probably to a water/leaves transfer during paddy floodings



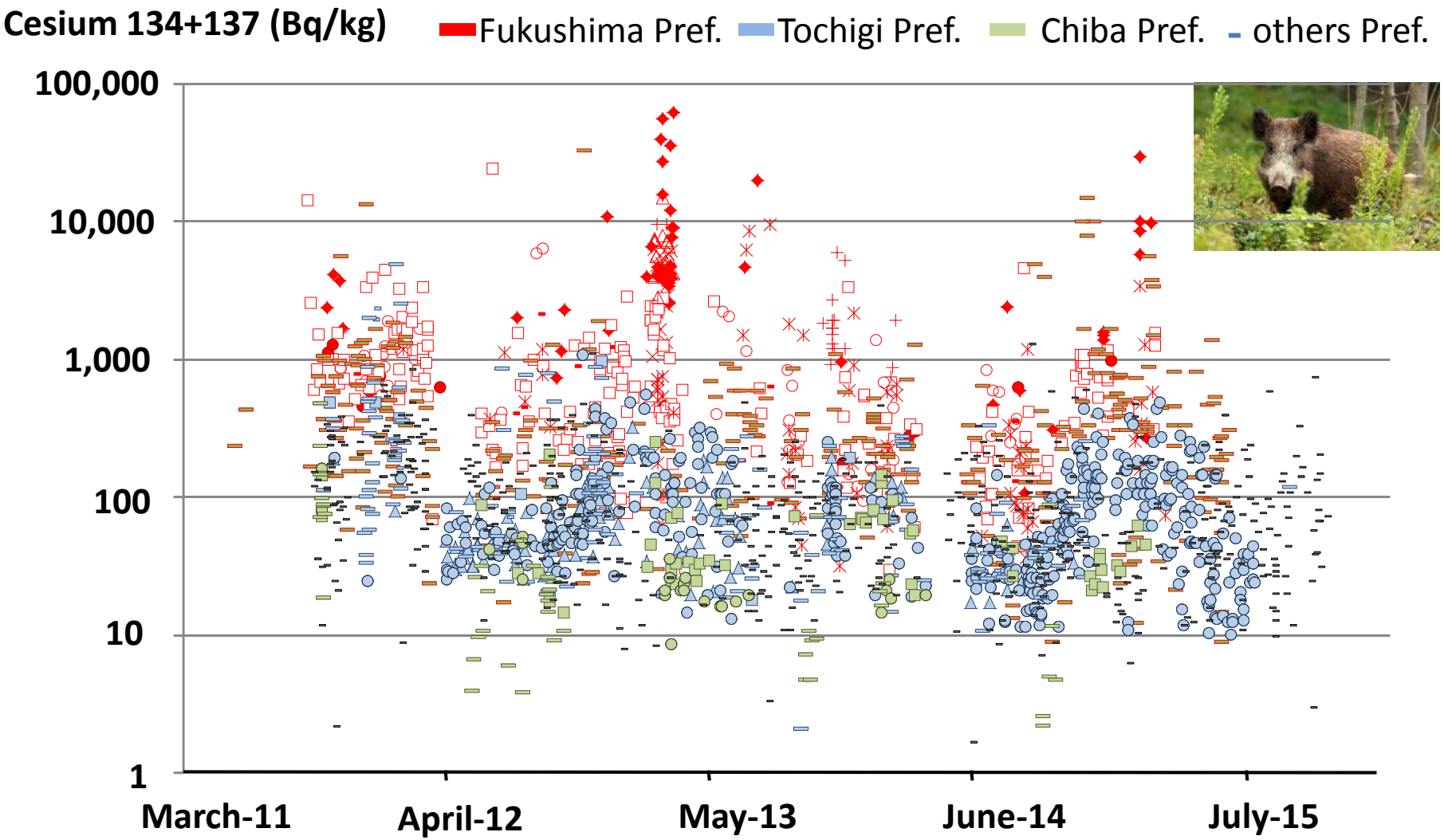


Activities of game meats

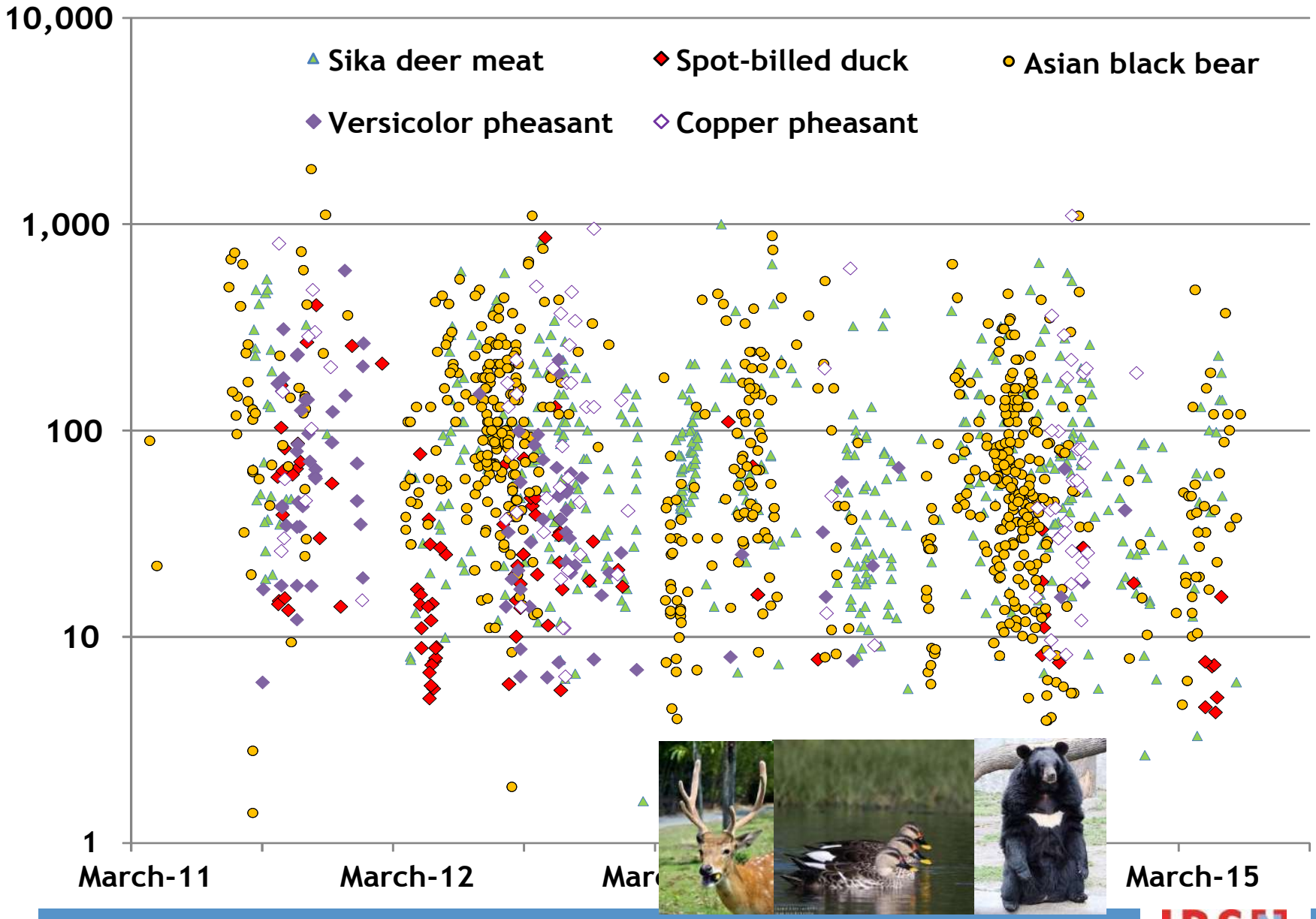
Still high activities, most often far above consumption limits



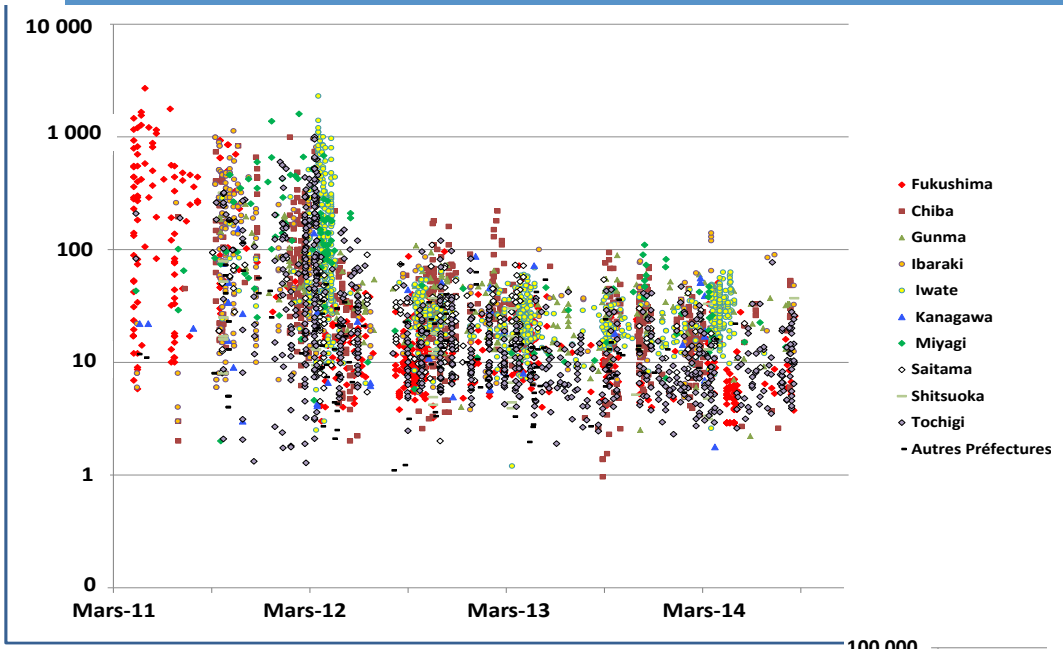
Activities of game meats



Activities of game meats



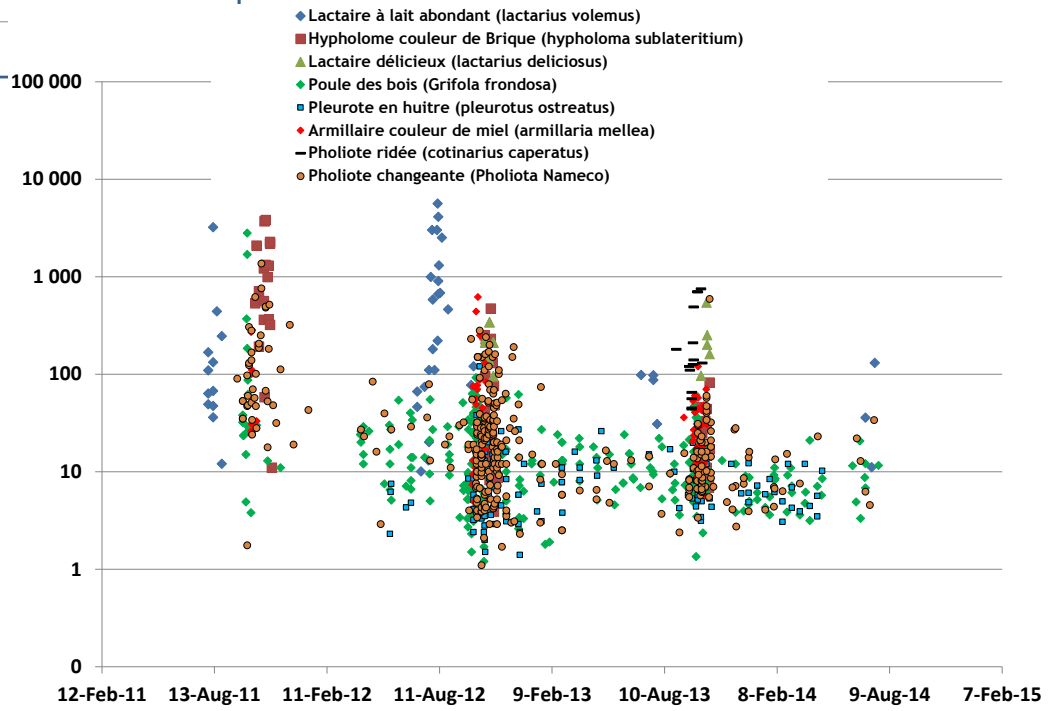
$^{134}Cs+^{137}Cs$ activities in mushrooms and edible wild plants plants



Little spatial variability

Strong between-species variability

Long-term persistence



$^{137+134}$Cs activities of foodstuffs (synthesis)

from most contaminated but non-evacuated areas

Bq/kg fresh[1]

	2011	2012	2013	2014 and 2015
10 000	**Leafy-vegetables** *Ponct :* Boar meat *very ponct . :* Beef	*Ponct :* Boar meat	*Ponct :* Boar meat	
1 000	**Boar meat** *ponct .* Game meat Mushrooms Beef Bamboo shoots	**Boar meat** *ponct .* Mushrooms	**Boar meat**	*Ponct :* Boar meat
100	**Game meat** **Mushrooms** Some kinds of fruits[2] *ponct . Milk, meats* *crops*	**Game meat** **Mushrooms** *ponct . :* Rice, soy [3]… Bamboo shots	**Game meat** Most sensitive mushrooms *ponct . :* Rice, soy [3]… *Very ponct..* Bamboo shots	**Game meat** Most sensitive mushrooms
10	**Milk Meats,** **Crops**	**Fruits, Beef** Bambou shoots Vegetables	**Mushrooms, Fruits** Bamboo shoots Rice soy [3]… *Ponct .* Beef, Vegetables	**Mushrooms** Bamboo shoots *Ponct .* Some kinds of Fruits Rice, soy [3]…
		Milk, Other meats **Wheat, barley,** **Vegetables**	**Milk, Other meats** **Wheat, barley,** **Vegetables**	**Milk, Meats** **Crops**

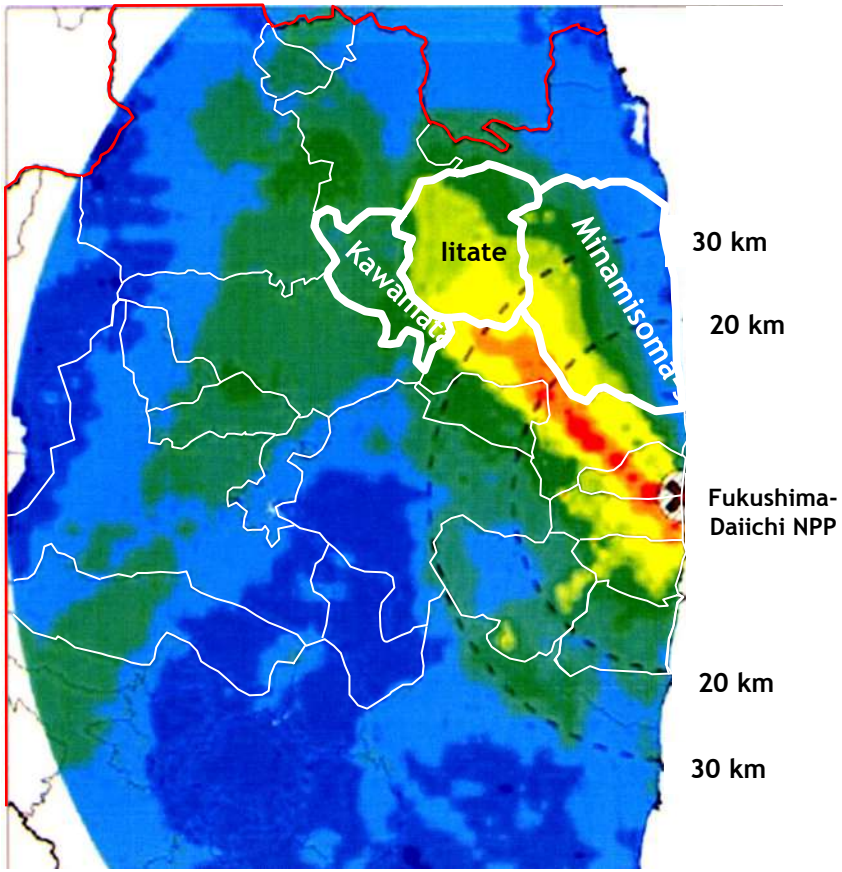
1 : Raw fresh products, 2 : Apricots, kiwis, persimmons, nuts species
3 : others kinds of bean : Blackwheat, red beans…

Assessments of effective doses potentially received by foodstuffs ingestion

For adults living on most contaminated localities, but non-evacuated, who would have consummed exclusively locally produced foodstuffs but respecting the consumption limits (assessments using japanese dietary habits)

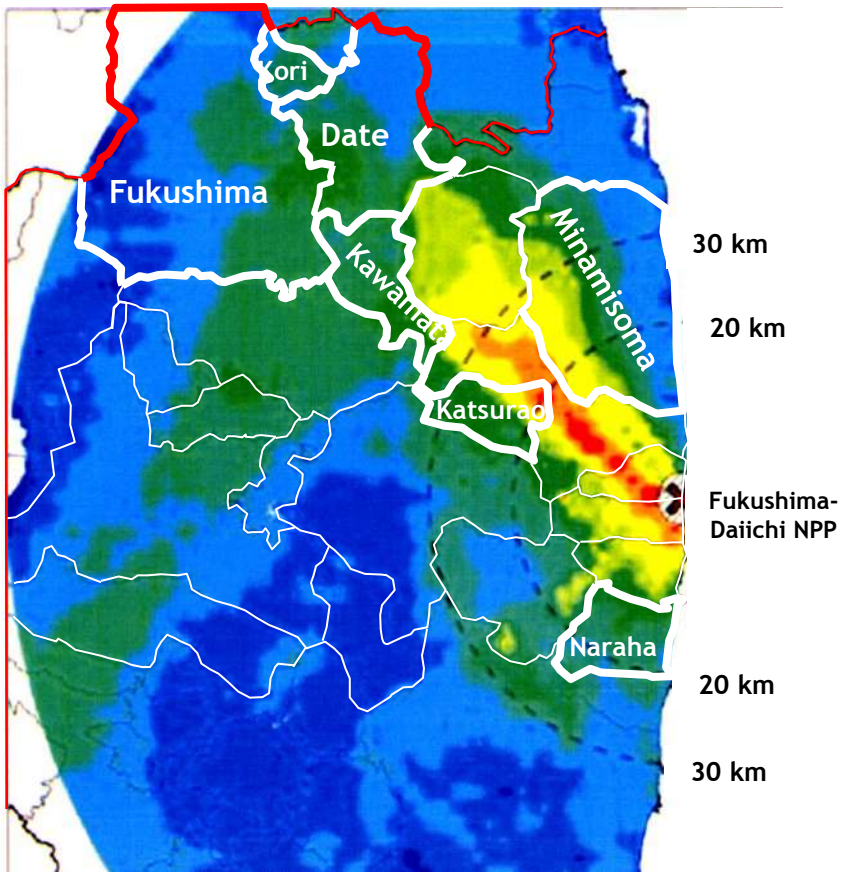
Effective dose for the period May-December 2011

0,6 mSv



Effective dose for 2013

0,3 mSv



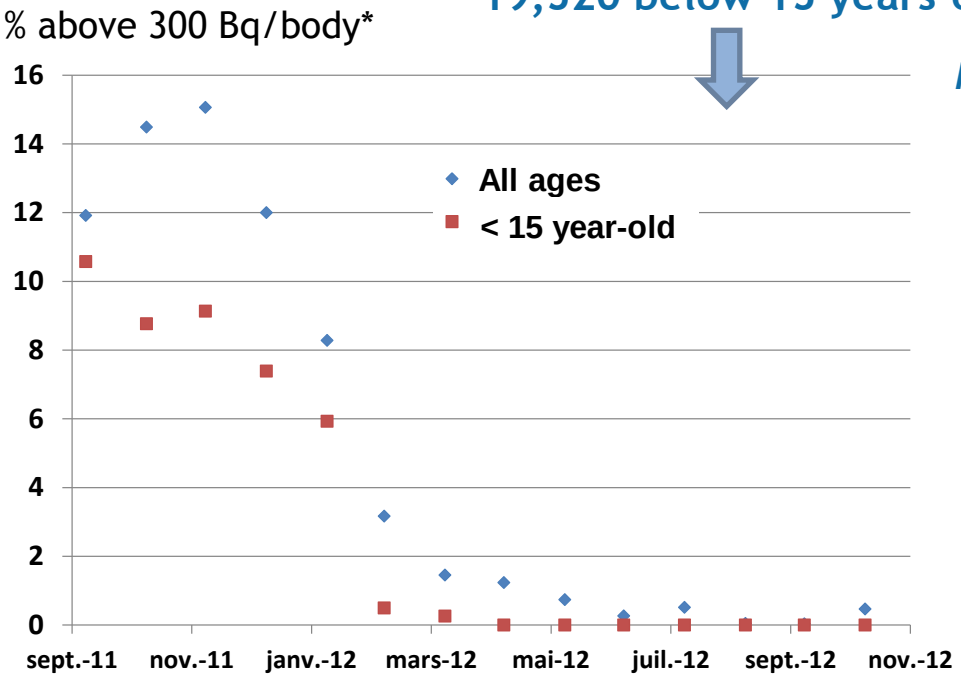
^{137}Cs Whole-body counting

	number of results
< 1 mSv*	106 070
1- 2 mSv	14
2- 3 mSv	10
> 3 mSv	2
Total	106 096

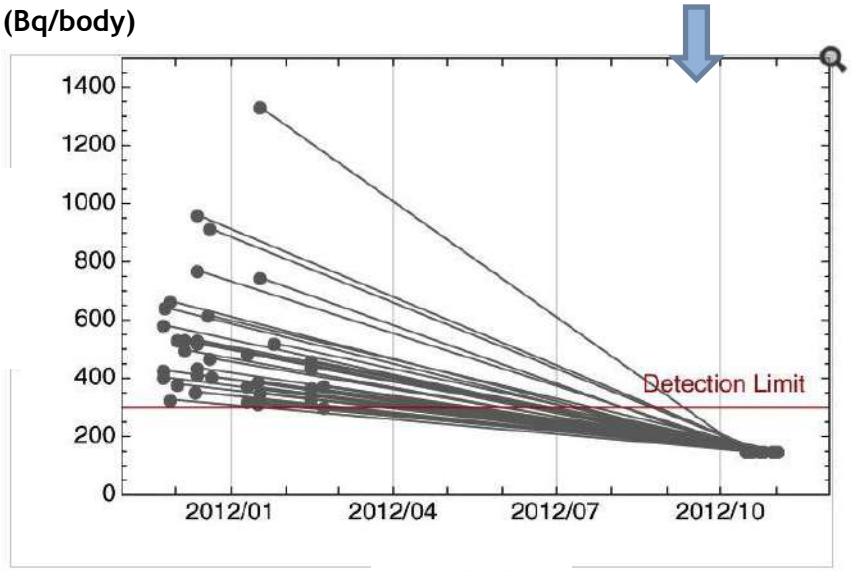
Whole-body counting results for the period June 2011 - December 2012

* 1 mSv = 30 000 Bq/boby (adult) = 400 - 450 Bq/kg

Whole-body counting results concerning 32,811 persons, including 19,520 below 15 years-old; maximum dose assessed: 1,1 mSv



Monitoring on 40 children above 300 Bq/body



*300 Bq/body ~ 21 µSv/an for 10 year-old child, ~ 13 µSv/an (15 year-old), ~ 10 µSv/an (adult)

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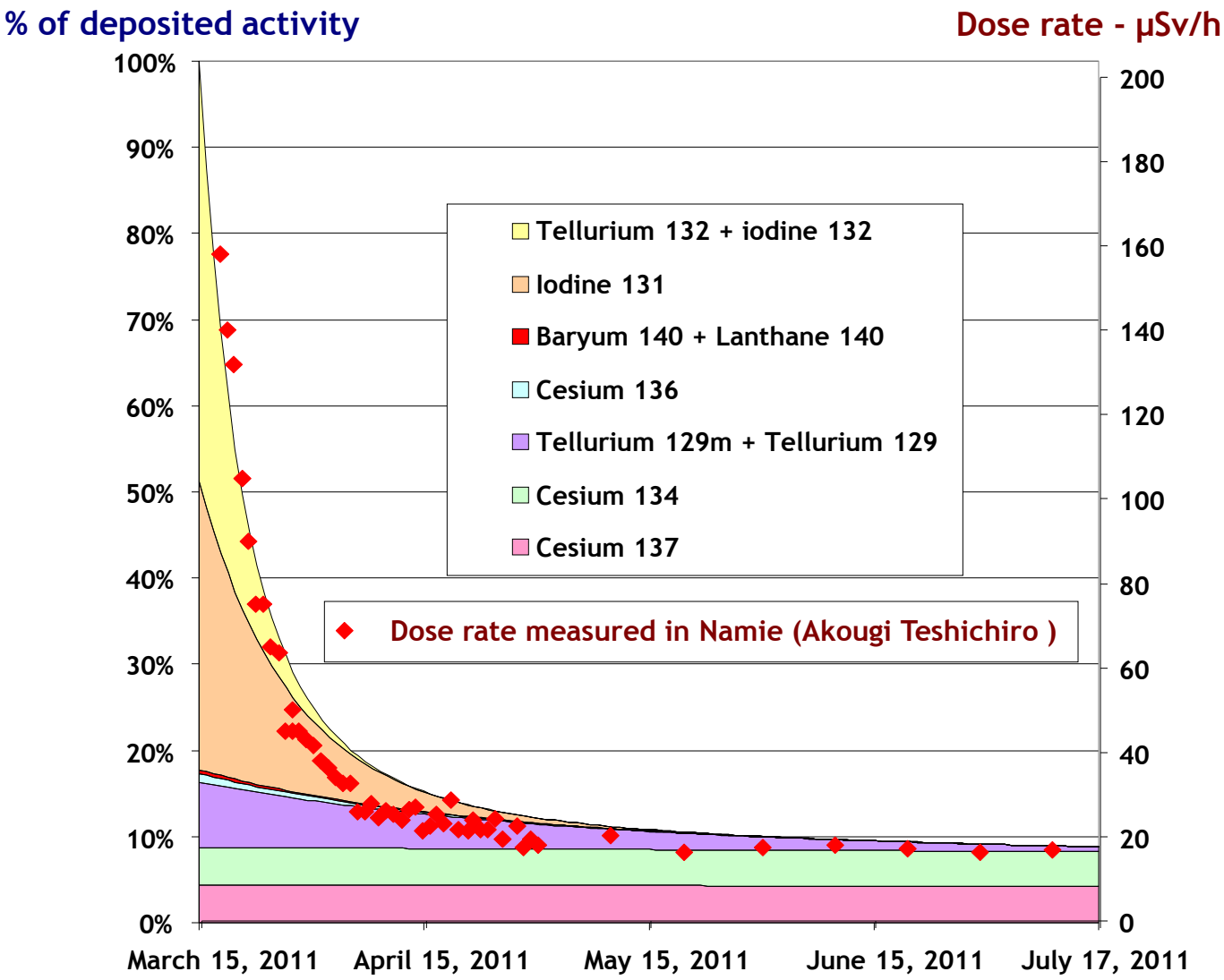
2nd part :

Evolution of dose rate in air and external doses

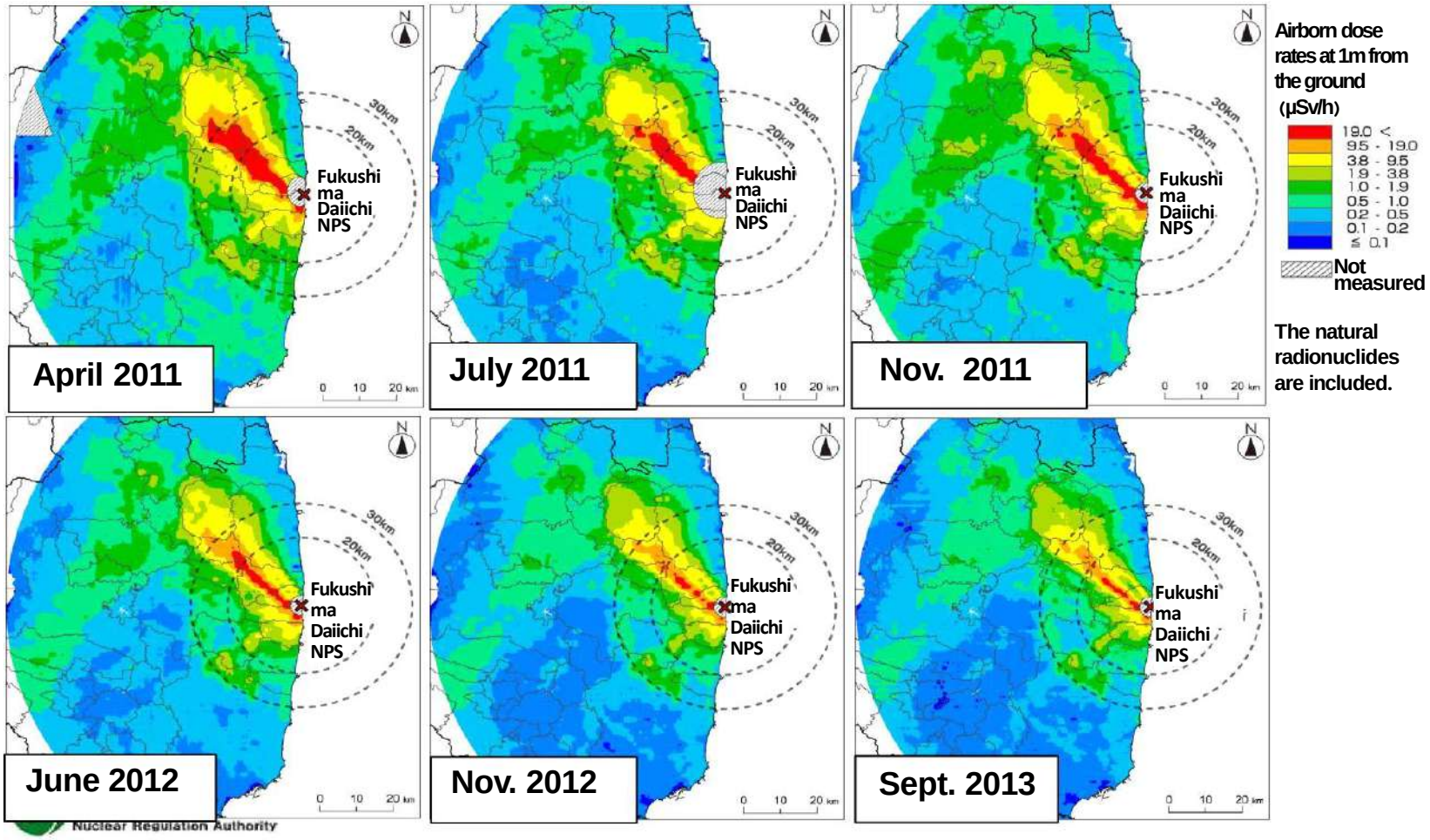
Evolution of dose rate in air during months following deposits



Dose rate in air falls down quickly after deposits due to the radioactive decay of short-life radionuclides; two months after deposits, it is mainly due to cesium

Evolution of airborne dose during the 2 firsts years

Maps of airborn dose rate at 1 m above soil, 80km around the Fukushima power plant, as seen by 6 among the 9 firsts airborned campaigns



The dose rate has decreased more quickly than expected by the decay of ^{134}Cs

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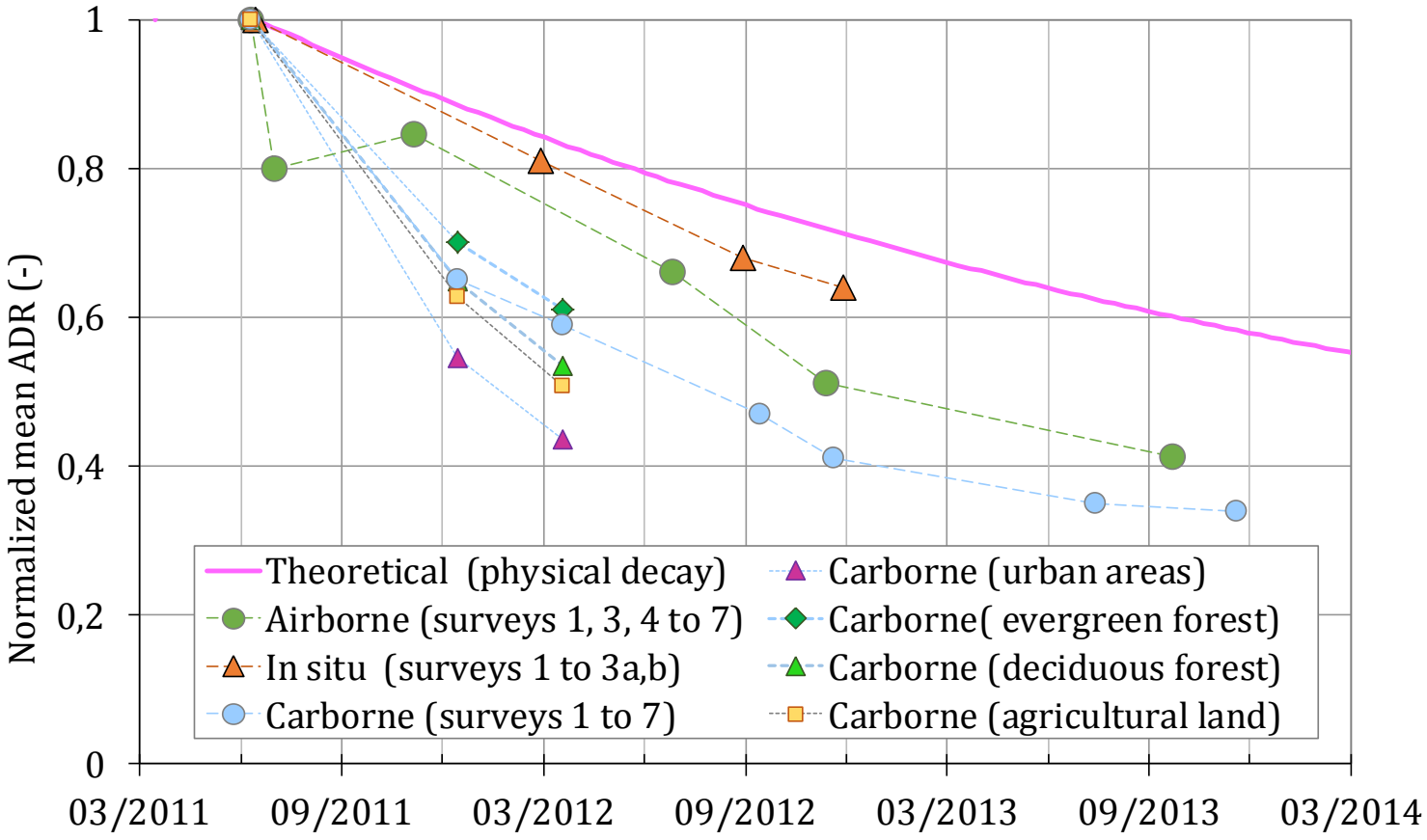
Decrease of air dose rate



Dose rate decreases at different rates depending on the kind of surface

This decrease could be be linked to cesium moving:

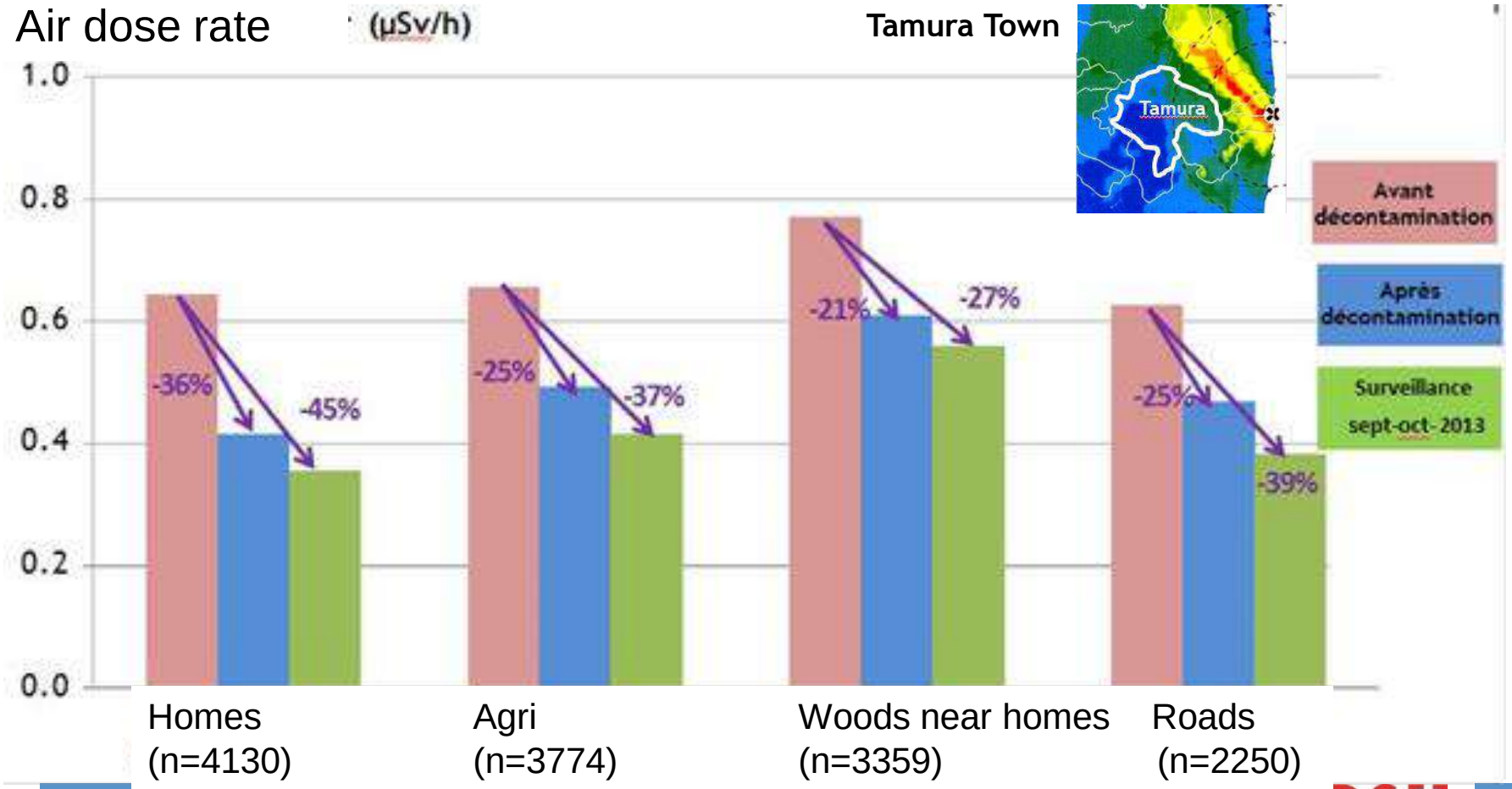
- **The falling of tree leaves (measurement bias), depth migration, run-off…**
- **Remediation actions: ploughing, surface washout (artificial notably)…**

Efficiency of remediation actions

Variable efficiency, depends on the type of environment and on initial dose rate : highest efficiency for highest dose rate

Mean reduction factor in terms of dose: 20 to 50%

Mean reduction factor in terms of activity: 50 to 70% by washing artificial surfaces; 80 to 90% by removing top soil layer



Air dose rates *vs* individual effective doses by external pathway

- Inside house, dose rate is lower than outside

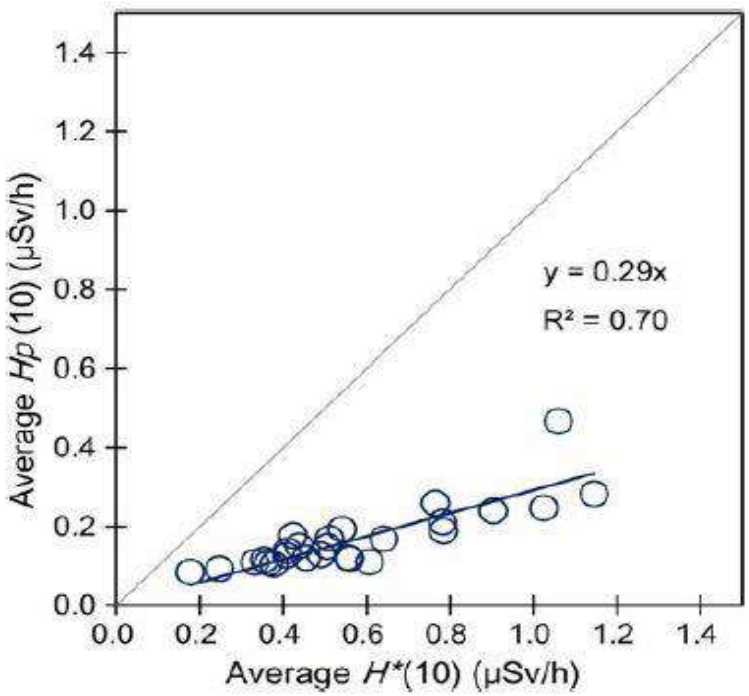
- Usely, considering 16h/d inside

Theoretical effective dose = ½ dose in outside air

(operationally used by japanese, considering that 0,23 µSv/h allows respecting 1 mSv/an)

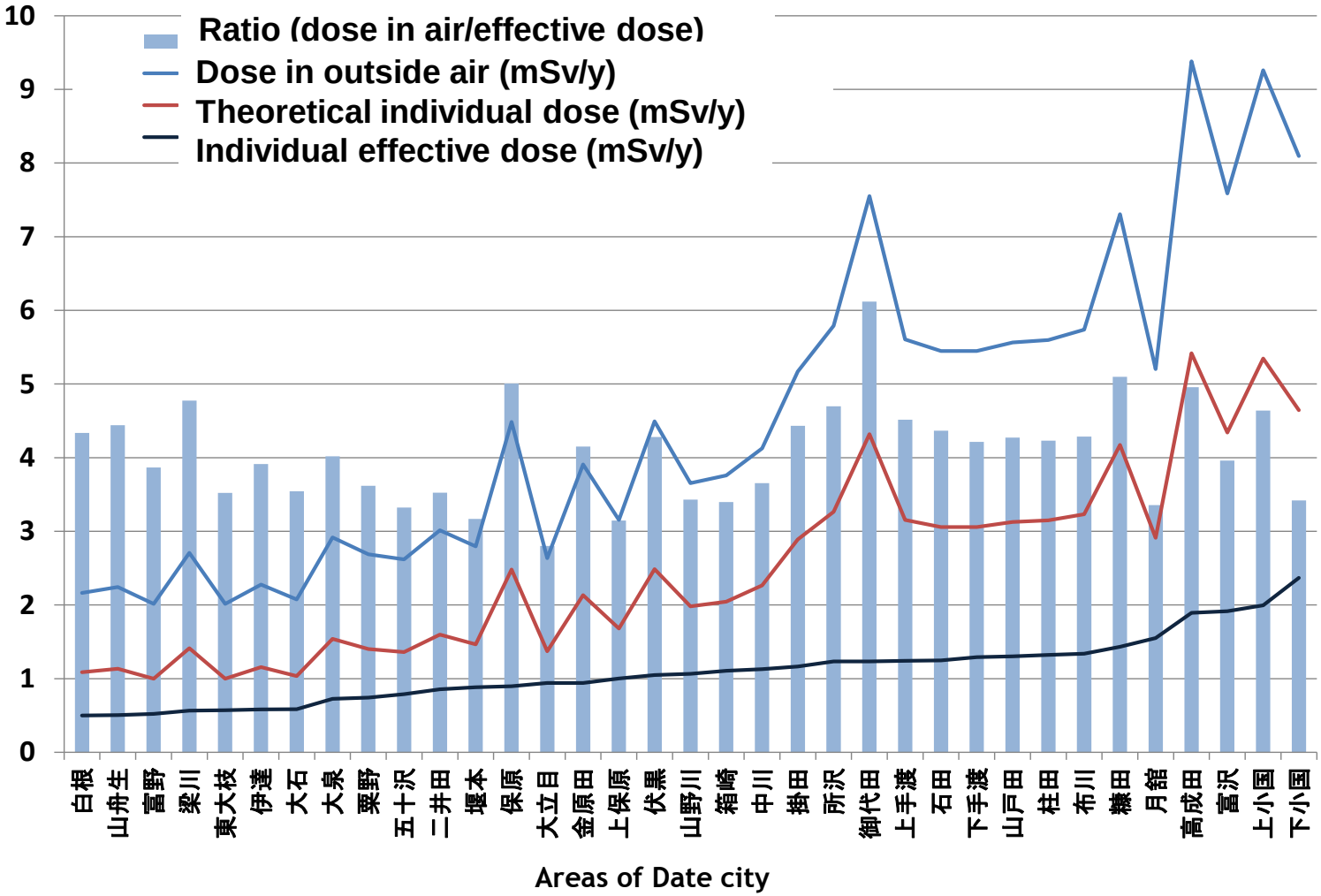
- The measurement results of individual monitoring show that:

Effective dose = 1/3 to 1/5 dose in outside air



Air dose rates *vs* individual effective doses by external pathway

Individual monitoring of 53,000 persons (july 2012 to June 2013) and 18,700 persons (July 2013 -June 2014) from various areas of Date city



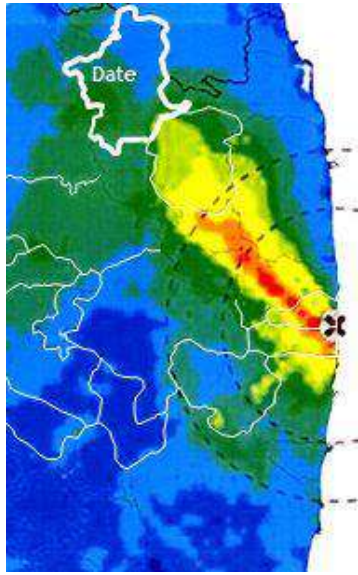
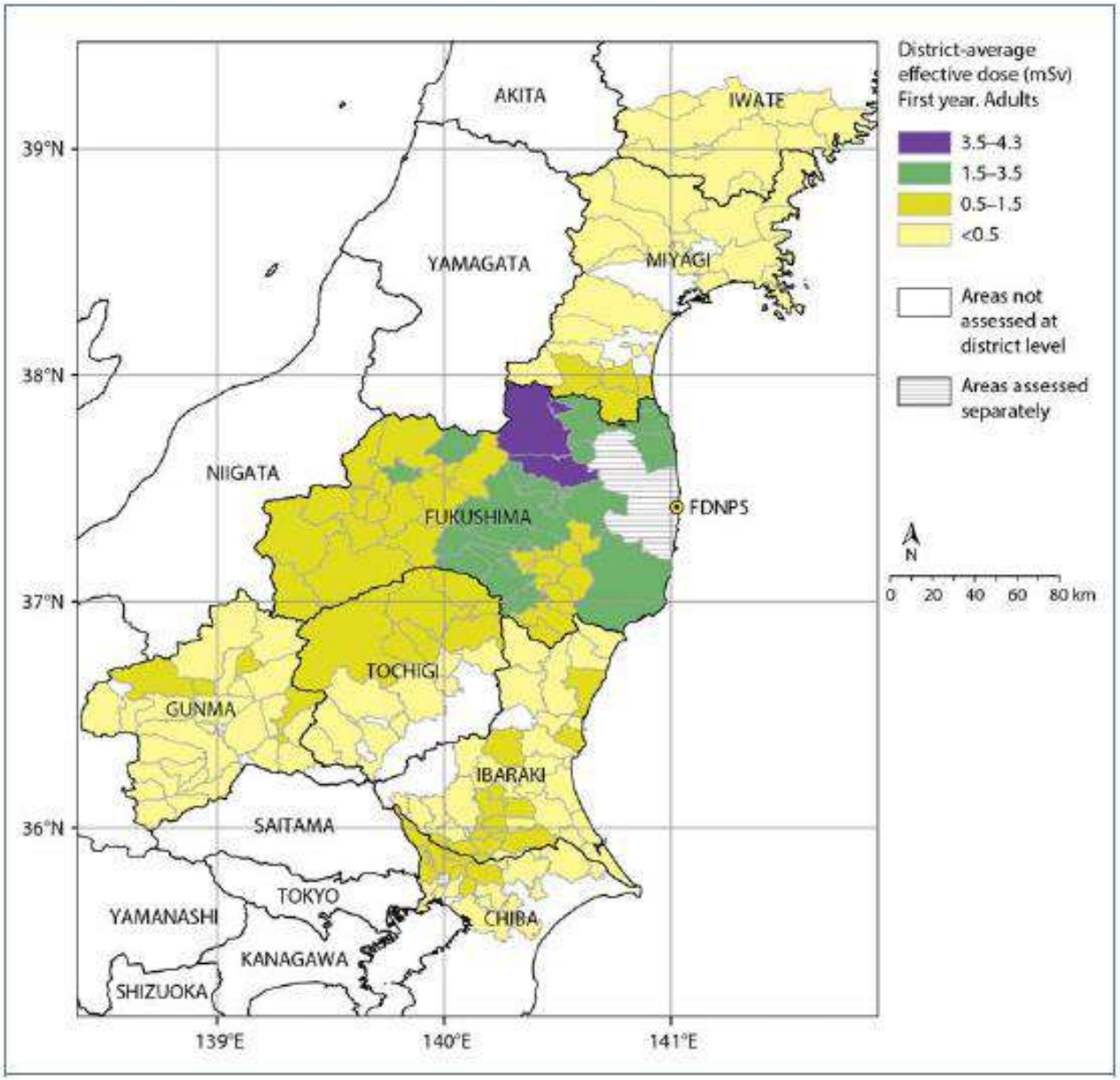


Figure VI. Estimated district-average effective doses in the first year following the accident to adults living in districts of Fukushima Prefecture and some districts of Group 3 prefectures that were not evacuated

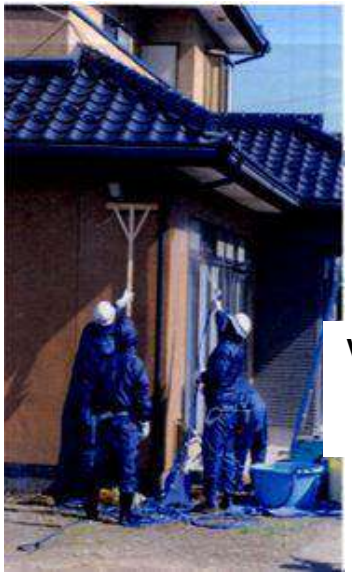
The effective doses include contributions from all relevant pathways and radionuclides



UNSCAER, 2013


Thanks for your attention

Remediation actions



Washing and brushing of roofs and walls with pressured water, sanding…

The remove of soil around a school

Cleaning a drain piping

Suction of cleaning water

Removing of litter close to a house

removing a "hot spot" a the bottom a discharg pipe of a gutter

Street cleaning

Remediation actions

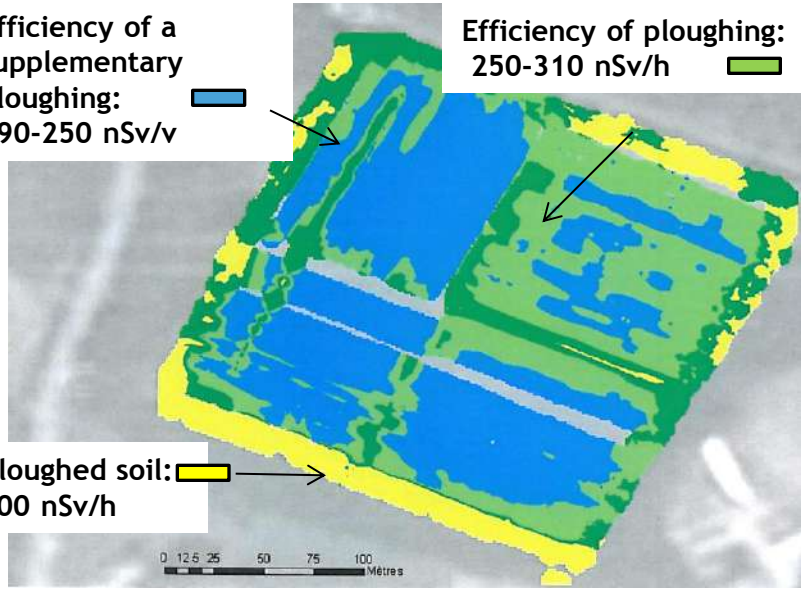


size and tree trimming, lawn mowing


Efficiency of a supplementary ploughing: 190-250 nSv/v

Efficiency of ploughing: 250-310 nSv/h

Non-ploughed soil: 400-600 nSv/h



Actions de décontamination

Sand or steal-balled blasting

Ice blasting

Ultra-high pression cleaning

Asphalt removing

Fixing spray for soil

Cleaning…

3-5µSv/h→ <1.5µSv/h