# Management and Evaluation of the Forest Fire Situation in the Exclusion Zone and Zone of Unconditional (Mandatory) Resettlement

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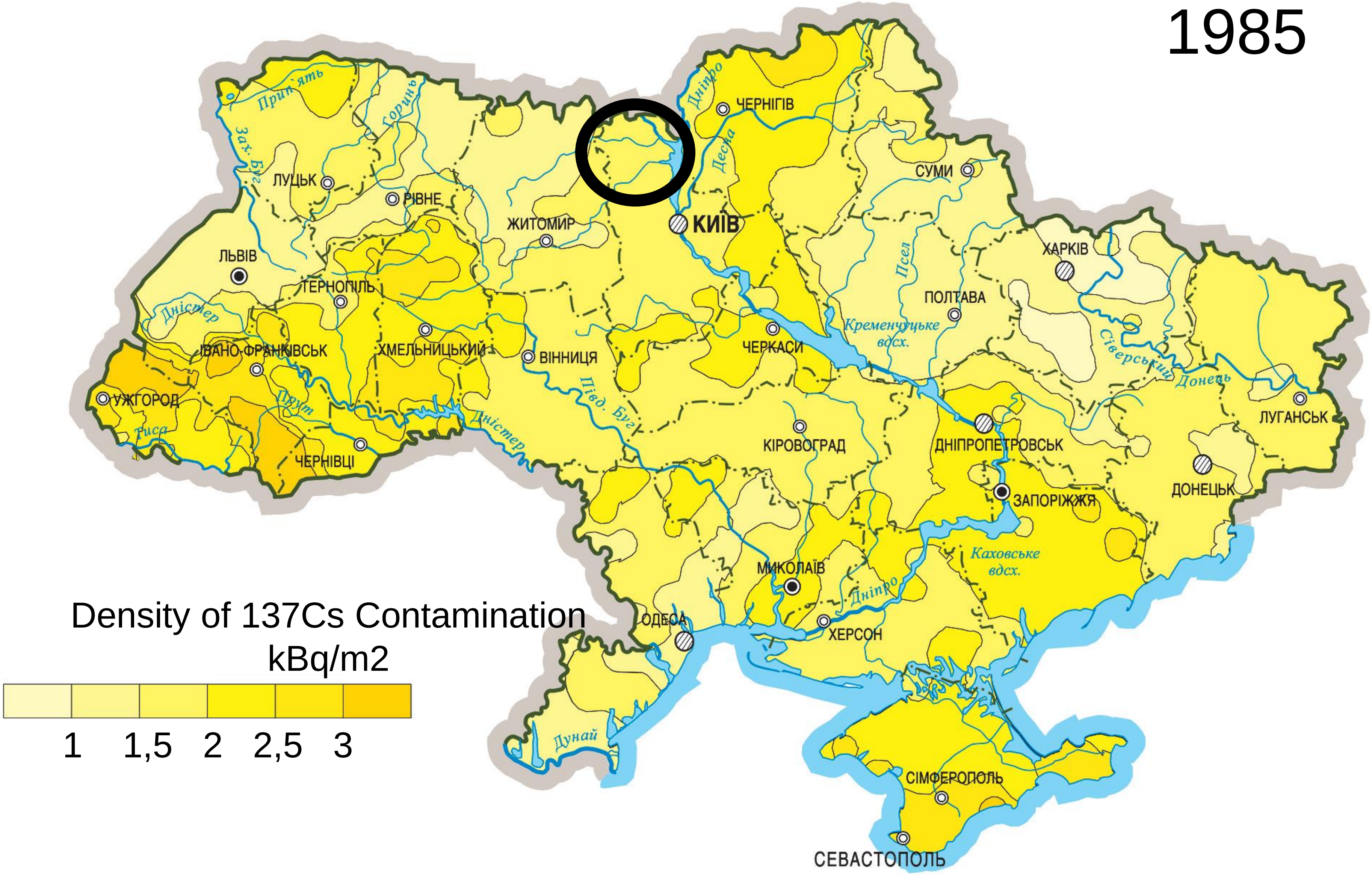
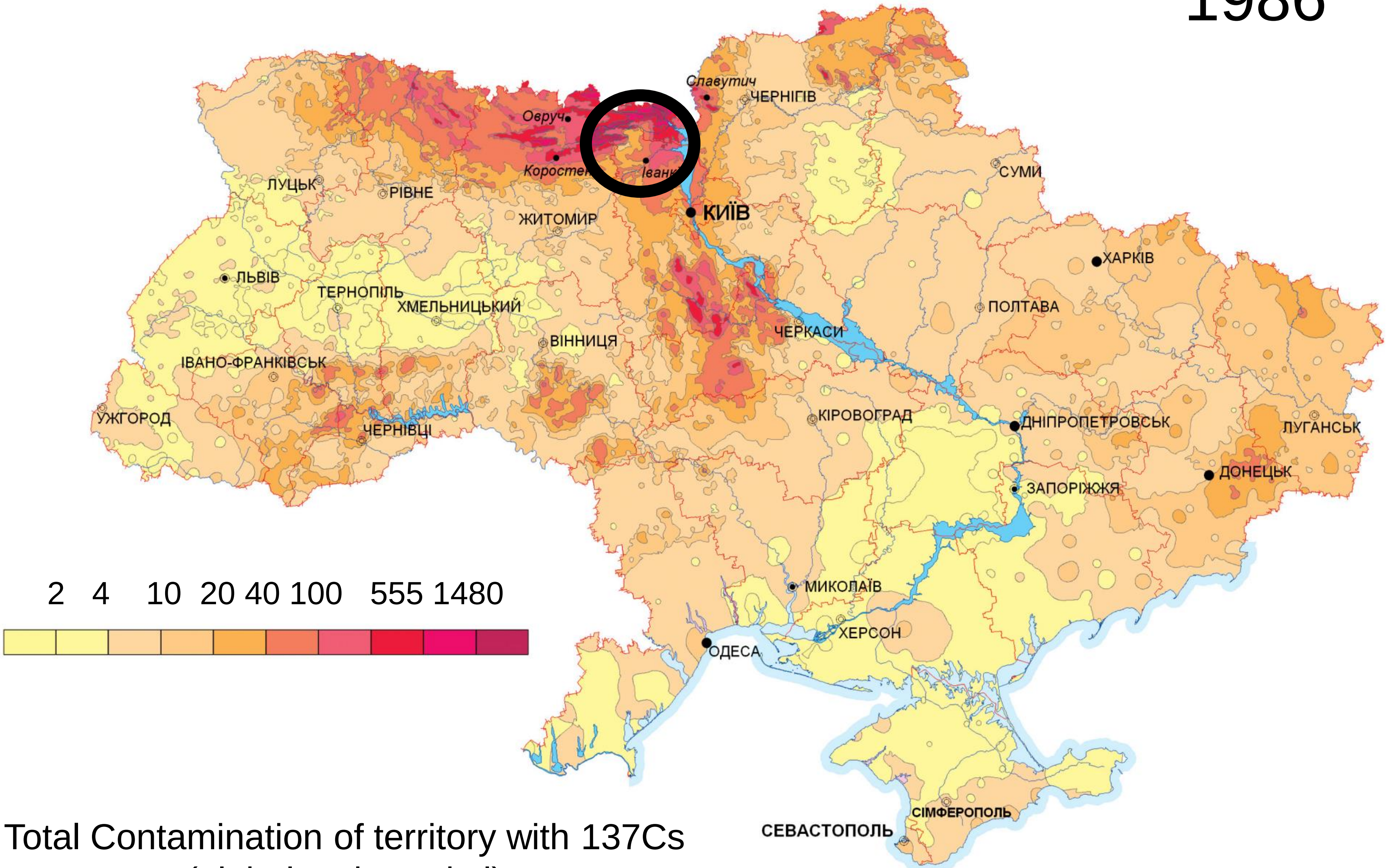
1985



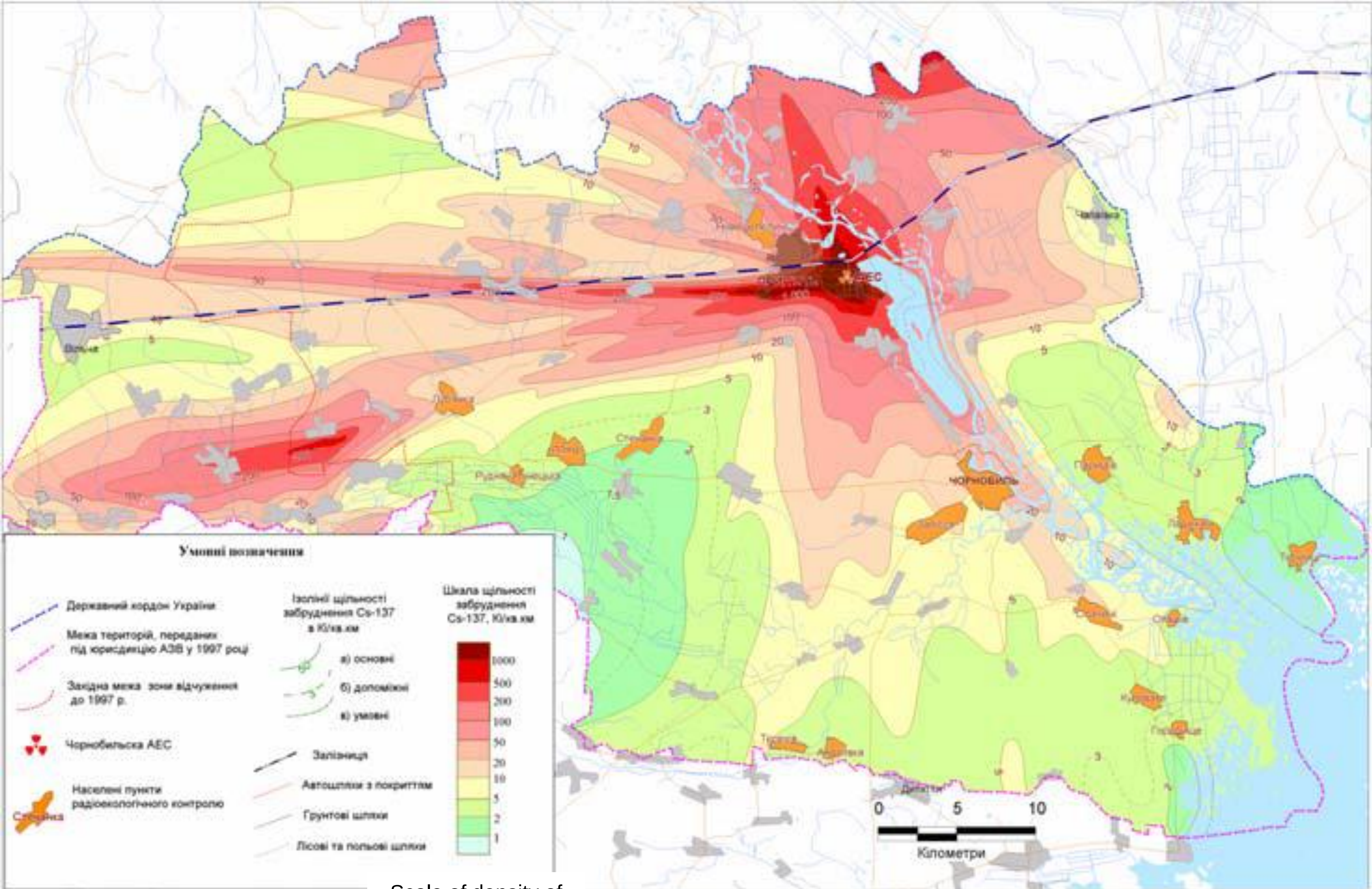

Density of 137Cs Contamination
kBq/m2

1 1,5 2 2,5 3

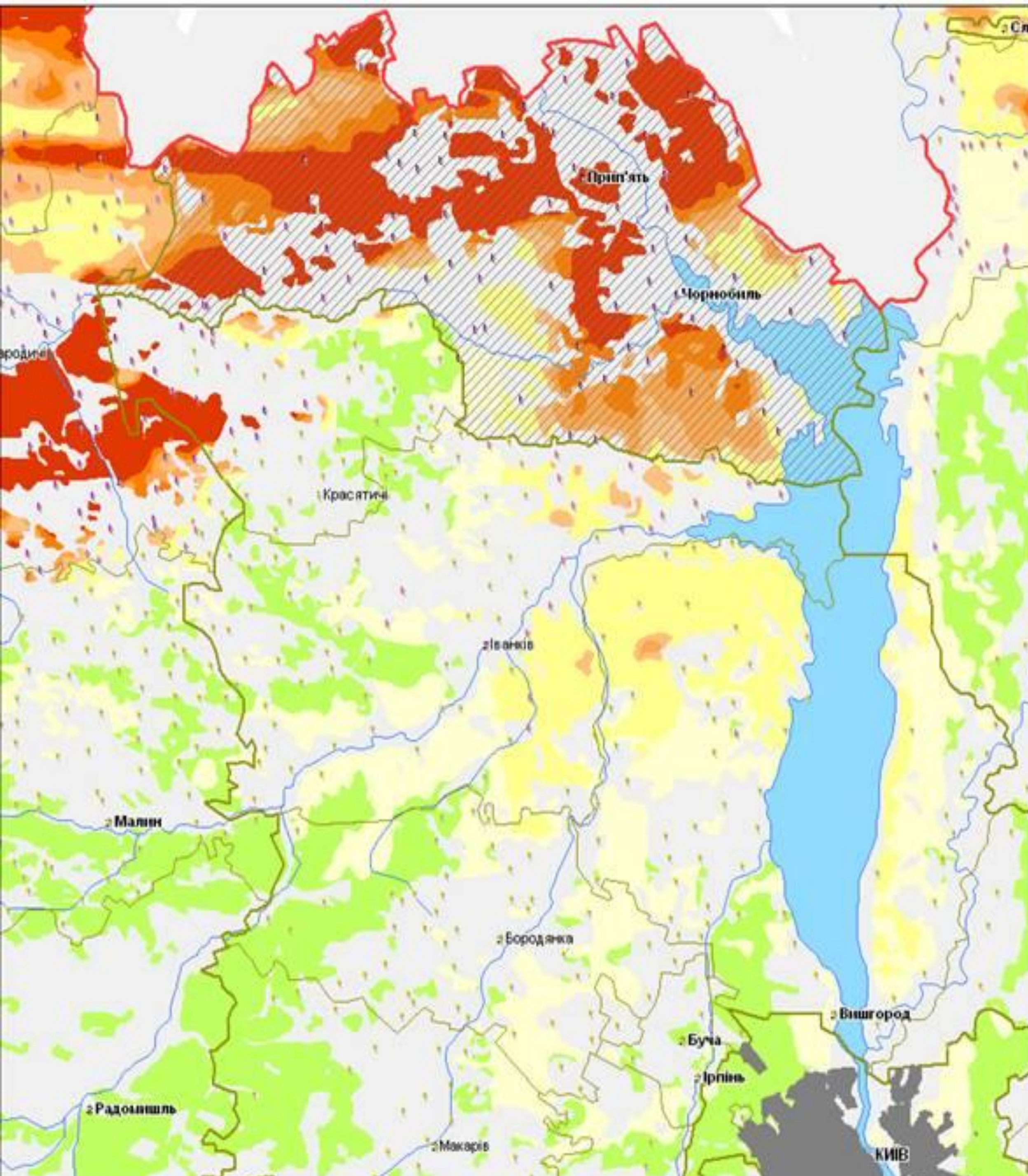
1986



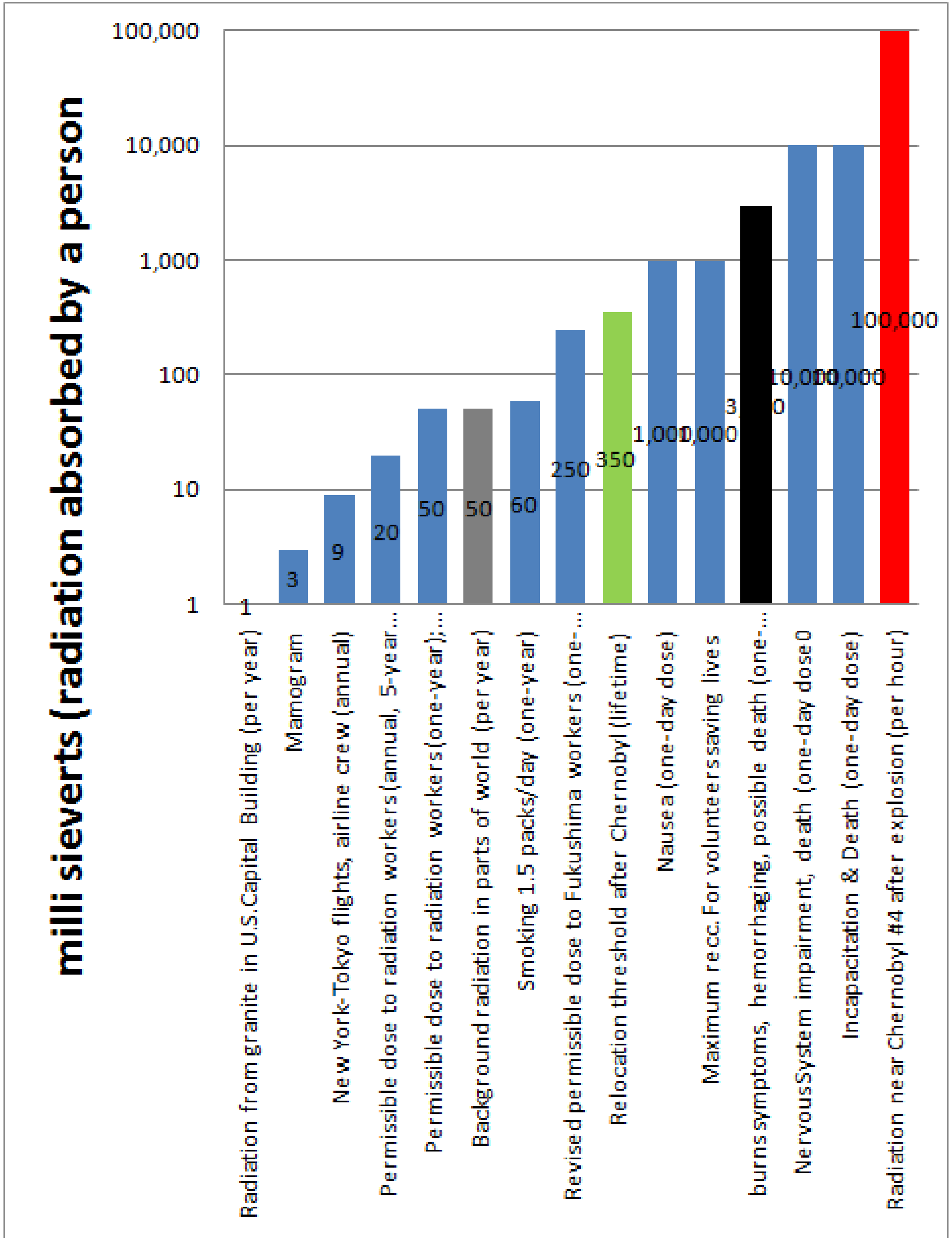

Total Contamination of territory with 137Cs
(global + chornobyl)
kBq/m2




Scale of density of contamination by 137Cs

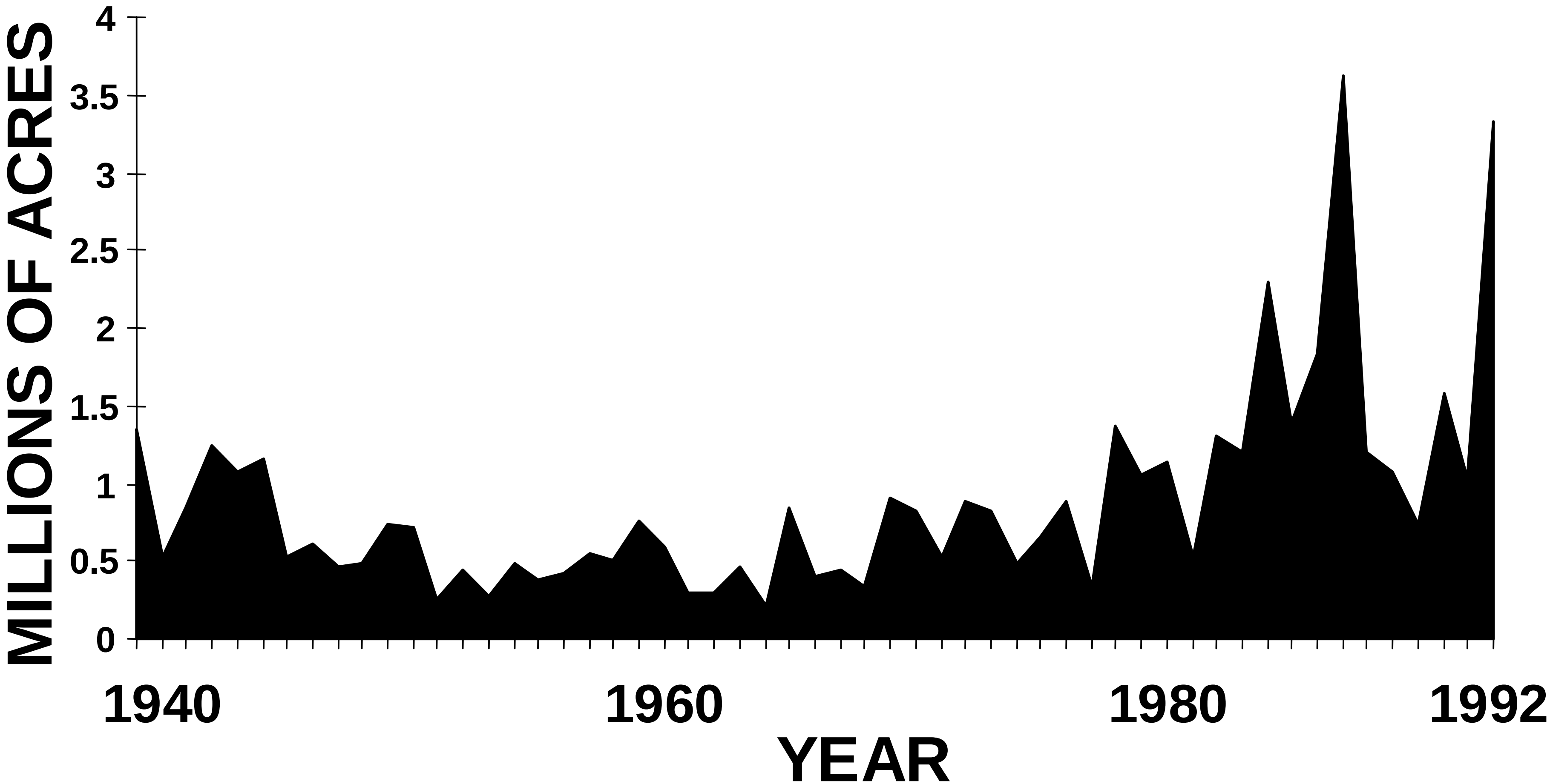



| Zone | Contamination | Restrictions |
| --- | --- | --- |
| 1st | > 555 kBq/m$^2$ | Development of the special regime for forestry. Limitation of the working time |
| 2$^{nd}$-c | 370- 555 kBq/m$^2$ | Limitation of utilization of wood for the people's needs |
| 2$^{nd}$-b | 370- 259 kBq/m$^2$ | Not allowed to use wood as the fuel and to manufacture the domestic goods and facilities for the foodstuff storing |
| 2$^{nd}$-a | 185- 259 kBq/m$^2$ | Limitation of utilization of the fuel and hungry wood and meat of the wild animals. Prohibition to hunting roe |
| 3th-b | 74- 185 kBq/m$^2$ | Prohibition of consumption of the wild berries and mushrooms. Limitation of utilization of the medical plants and wild animals |
| 3th-a | 37-74 kBq/m$^2$ | Limitation of utilization of the mushrooms, wild berries and some medical plants |
| | <37 kBq/m$^2$ | Utilization of the forest products without limitation |


milli sieverts (radiation absorbed by a person)
100,000
10,000
1,000
100
10
1
1
3
9
20
50
50
60
250
350
1,000
1,000
3,000
10,000
10,000
100,000
Radiation from granite in U.S.Capital Building (per year)
Mamogram
New York-Tokyo flights, airline crew (annual)
Permissible dose to radiation workers (annual, 5-year...
Permissible dose to radiation workers (one-year);...
Background radiation in parts of world (per year)
Smoking 1.5 packs/day (one-year)
Revised permissible dose to Fukushima workers (one-...
Relocation threshold after Chernobyl (lifetime)
Nausea (one-day dose)
Maximum recc. For volunteers saving lives
burns symptoms, hemorrhaging, possible death (one-...
NervousSystem impairment, death (one-day dose0
Incapacitation & Death (one-day dose)
Radiation near Chernobyl #4 after explosion (per hour)

# Crowded Forest, American West (Yakama Reservation)

# AREA BURNED ANNUALLY BY WILDFIRES IN THE WESTERN UNITED STATES, 1940-1994



**Scotts pine forest in Chernobyl radioactive zone, Ukraine. These forests are overly crowded and need thinning to reduce fire danger**

Photo, C. Oliver

# Radioisotopes found in Chernobyl Exclusion Zone Forests

**90 Sr** —common in CEZ, high dose coeff. for external exposure pthwys;
Half life: 20-28 years

**137 Cs** --common in CEZ, high dose coeff. for external exposure pthwys;
Half life: 30 years

**154Eu** --high dose coeff. for external exposure pthwys;
Half life: 9 years

**238Pu, 239Pu, 240Pu** —high dose coefficients for internal exposure pthwys;
Half life: 6,500 – 24,000 years

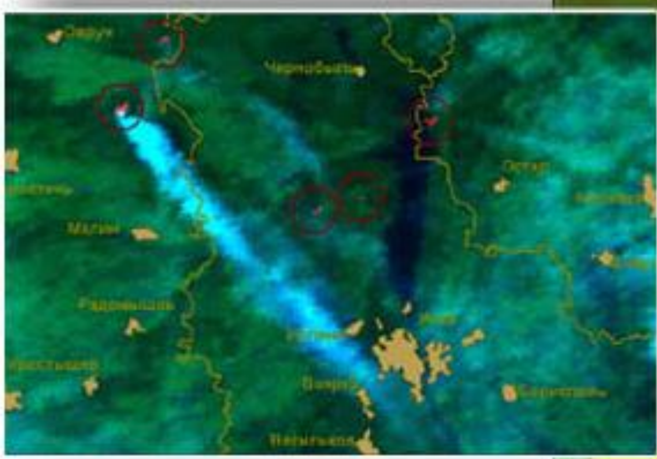
**241Am** —high dose coefficients for internal exposure pthwys.
Half life—432 years

Table 1. Estimated fuel component radionuclides in soil and vegetation of the 30-km Chernobyl exclusion zone in Ukraine in 2000 and 2010. Fuel component radionuclides in 2000 in upper 30-cm soil layer outside the ChNPP industrial site, excluding the activity located in the radioactive waste storages and in the cooling pond are from Kashparov et al. (2003). Estimates of concentration factors (ratio of radionuclides in vegetation and litter to soil) in forest and grasslands were derived from Lux et al. (1995), Sokolik et al. (2004), Yoschenko et al. (2006).

| Radionuclide | Radionuclide Inventory (Bq) | | | Ratio Combustible/Soil | |
|---|---|---|---|---|---|
| | Soil in 2000 | Soil in 2010 | Combustible in 2010 | Forest | Grassland |
| $^{90}Sr$ | 7.7E+14 | 6.1E+14 | 1.5E+14 | 0.351 | 0.023 |
| $^{137}Cs$ | 2.8E+15 | 2.2E+15 | 5.8E+13 | 0.101 | 0.037 |
| $^{154}Eu$ | 1.4E+13 | 6.4E+12 | 8.5E+10 | 0.031 | 0.005 |
| $^{238}Pu$ | 7.2E+12 | 6.7E+12 | 8.4E+10 | 0.03 | 0.004 |
| $^{239,240}Pu$ | 1.5E+13 | 1.5E+13 | 2.0E+11 | 0.031 | 0.005 |
| $^{241}Am$ | 1.8E+13 | 1.8E+13 | 4.7E+11 | 0.062 | 0.01 |

# Схема локалізації осередків пожеж в Київській та Житомирській областях 8 травня 2003 року


Фрагмент космічного знімку із супутника NOAA 08.05.2003, 18-30, наданого Українським центром менеджменту землі та ресурсів

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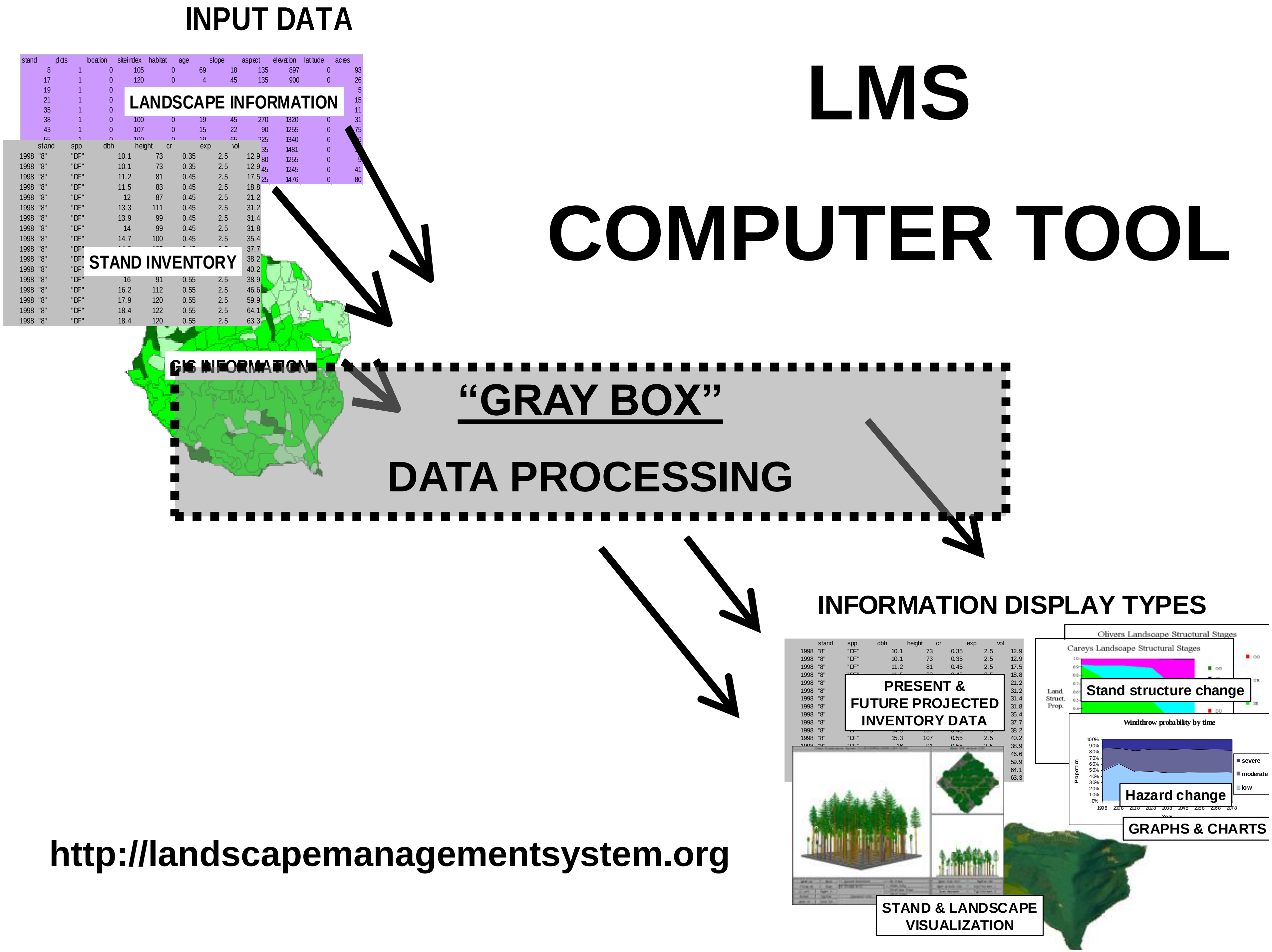
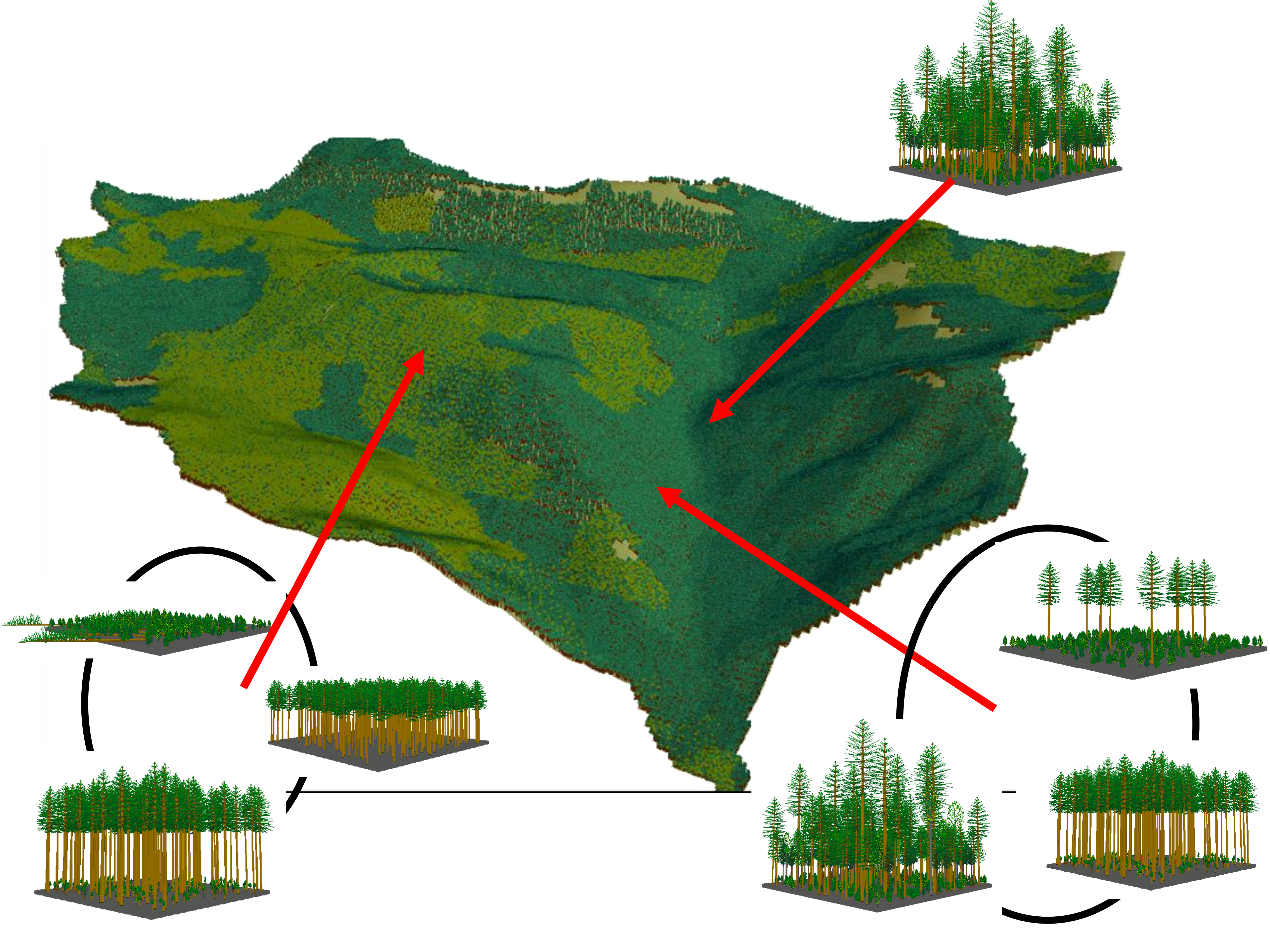
# LMS COMPUTER TOOL




http://landscapemanagementsystem.org



## Ukrainian Forest Service Inventory

## LMS Platform

The Landscape Management System (LMS, McCarter et al. 1998; Oliver et al. 2009) provides a variety of tools for examining management consequences on forested landscapes by analyzing each stand and linking results at the landscape level. (See http://Landscapemanagementsystem.org )

## FVS Growth Model

The Forest Vegetation Simulator (FVS, Dixon 2002, Wykoff et al 1982) - Lake States (LS) Variant was used for the forest simulations in this analysis.

## FVS Calibration

Aaron and Mykhaylo provided analysis showing differences in expected growth and the growth model used. For this example analysis the performance of red pine and scotch pine in the **Lake States variant** of FVS

## Ukraine Fire Risk Classification Rules

(See later slide)

## United States Forest Service, FVS, FFE, Crowning Index

(See later slide)

## GIS

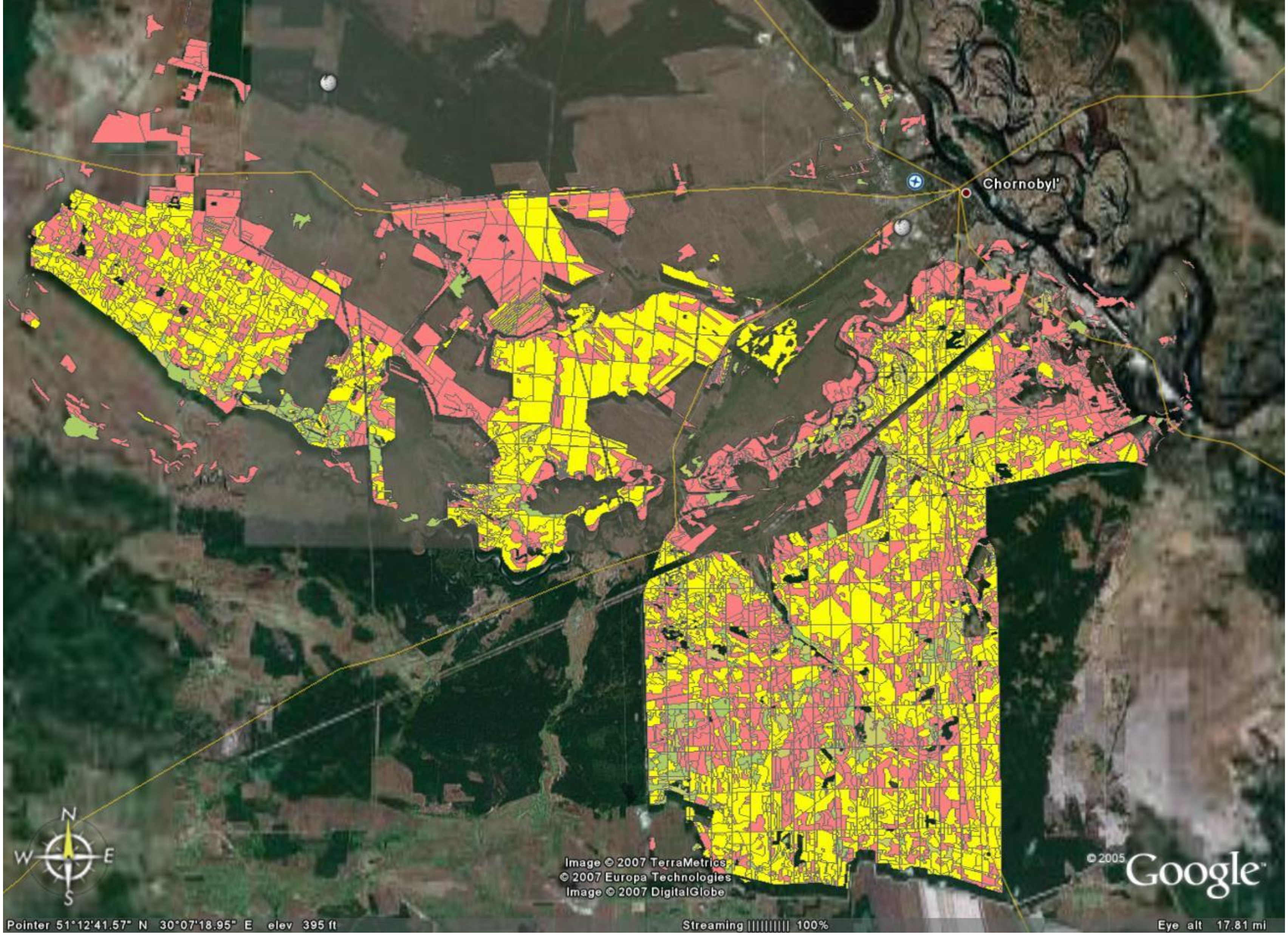



**Figure 4. Google Earth image showing Ukraine Fire Risk Classification on Chornobyl landscape. Note area to right of classified area which appears to be a large open area possibly from burns.**

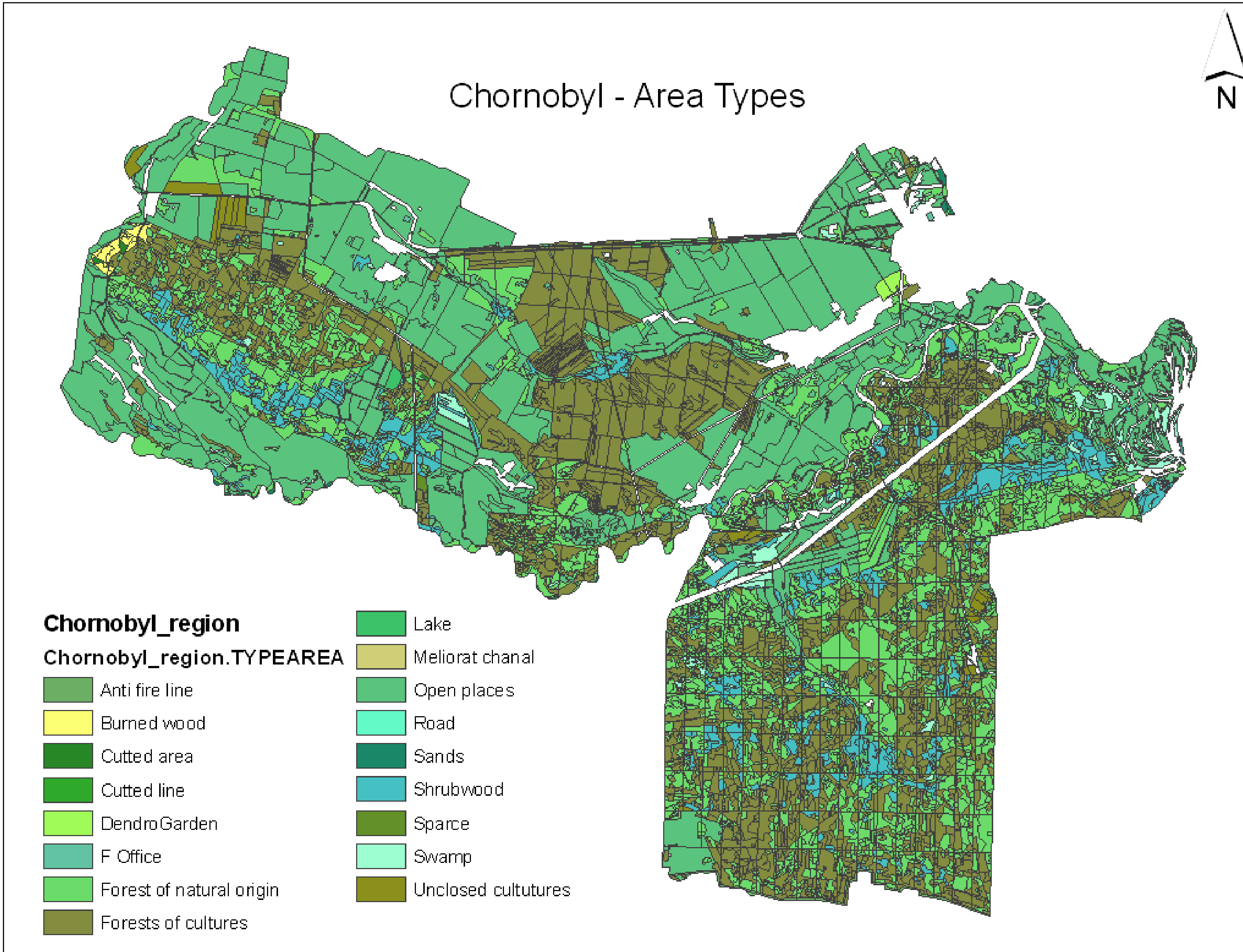
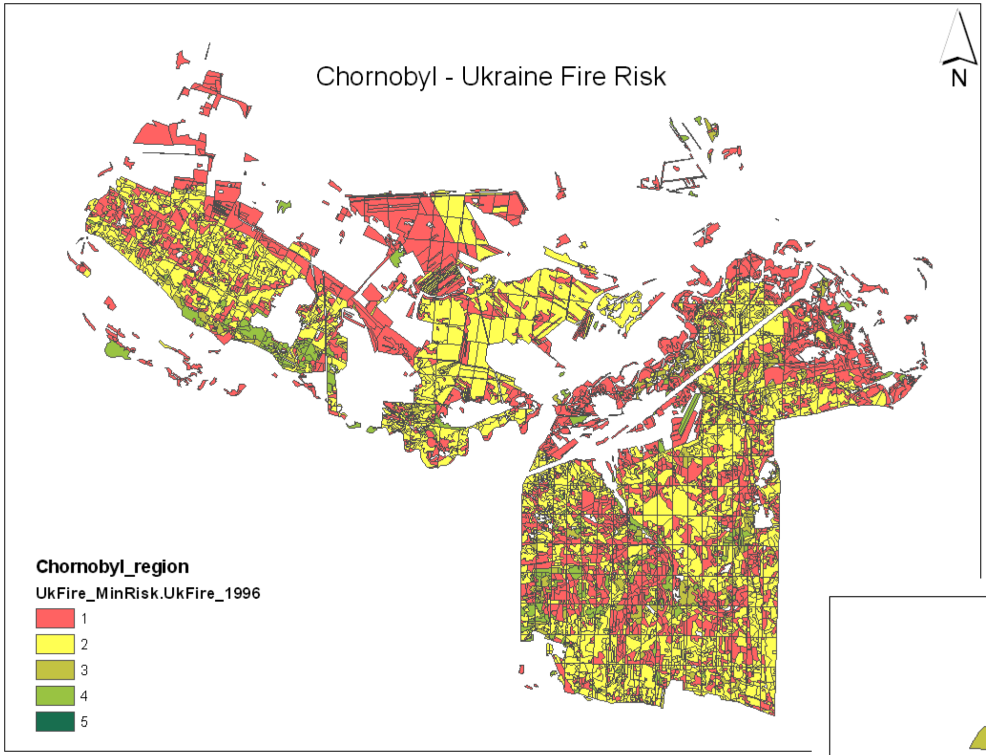
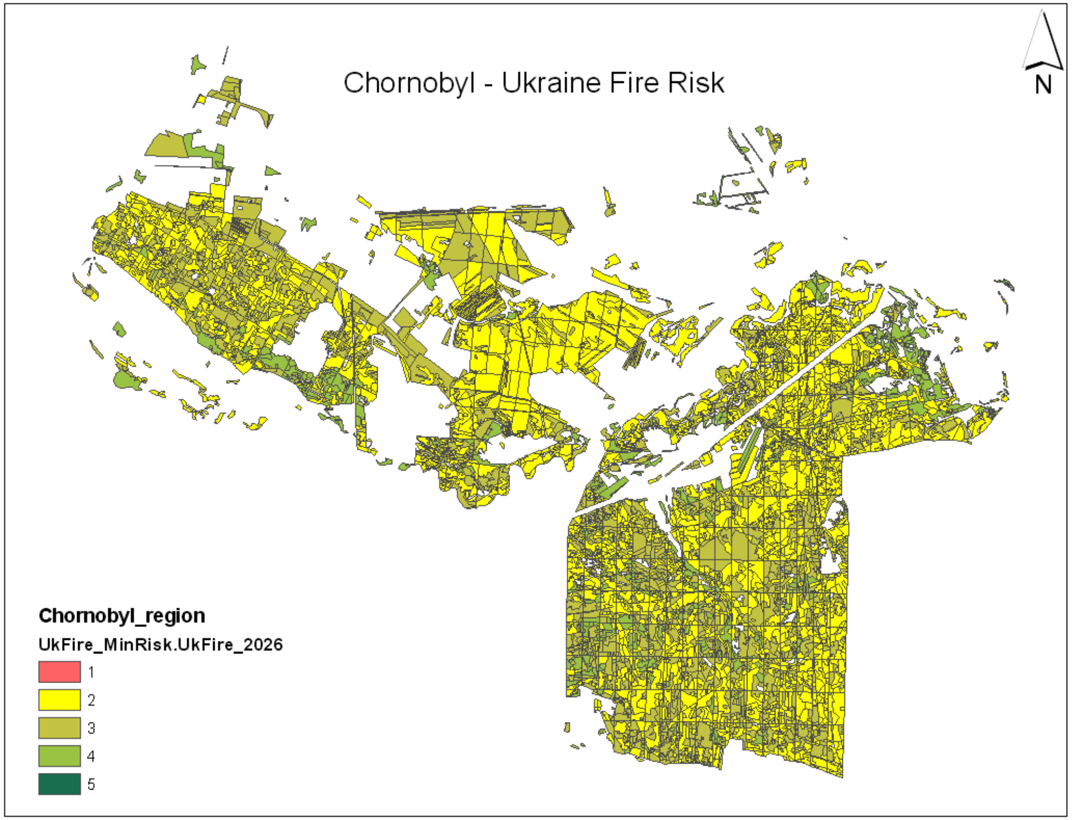



**Figure 1. Chornobyl area showing various vegetation types in the area.**

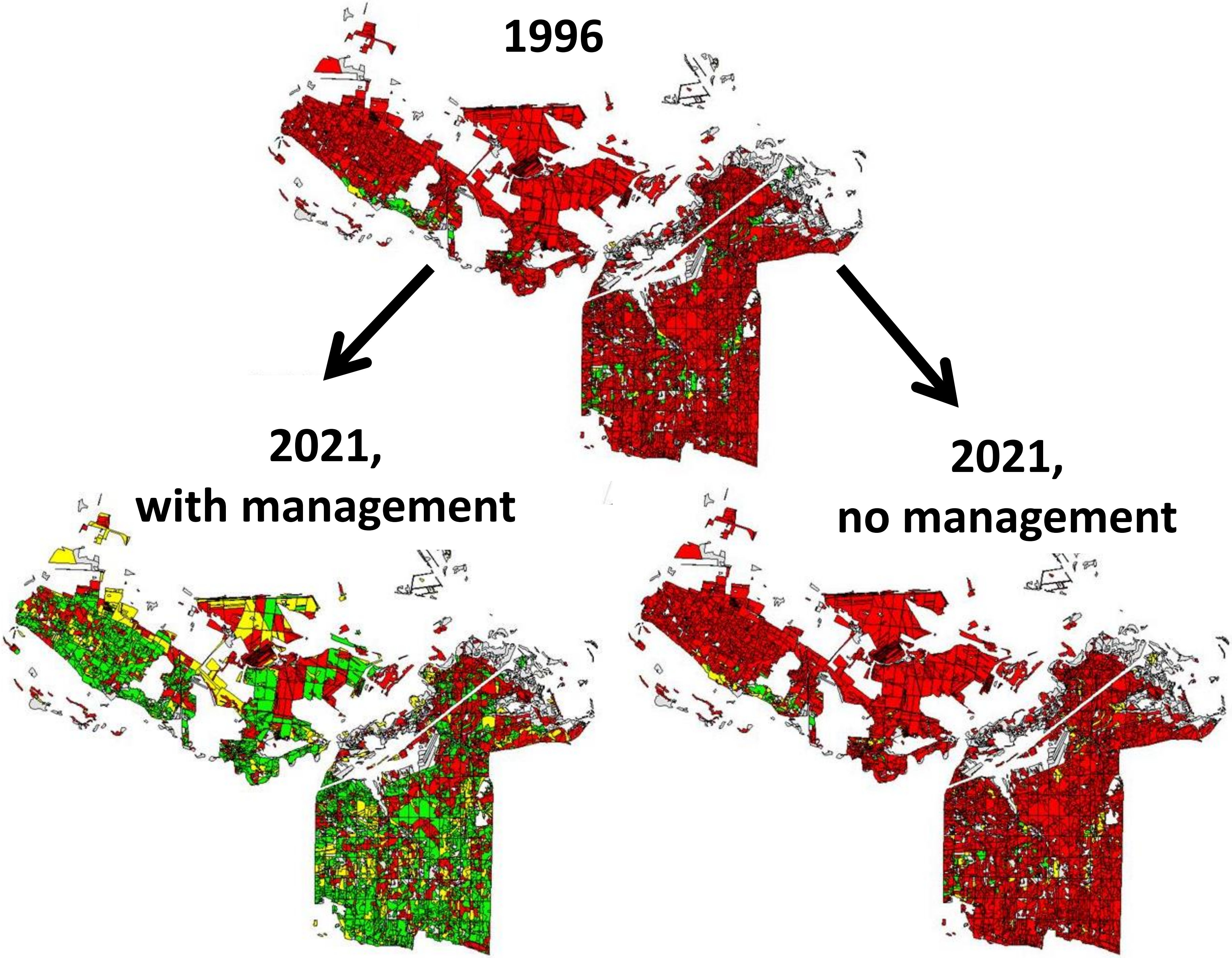



# <<1996




# Ukraine Fire Risk classes.

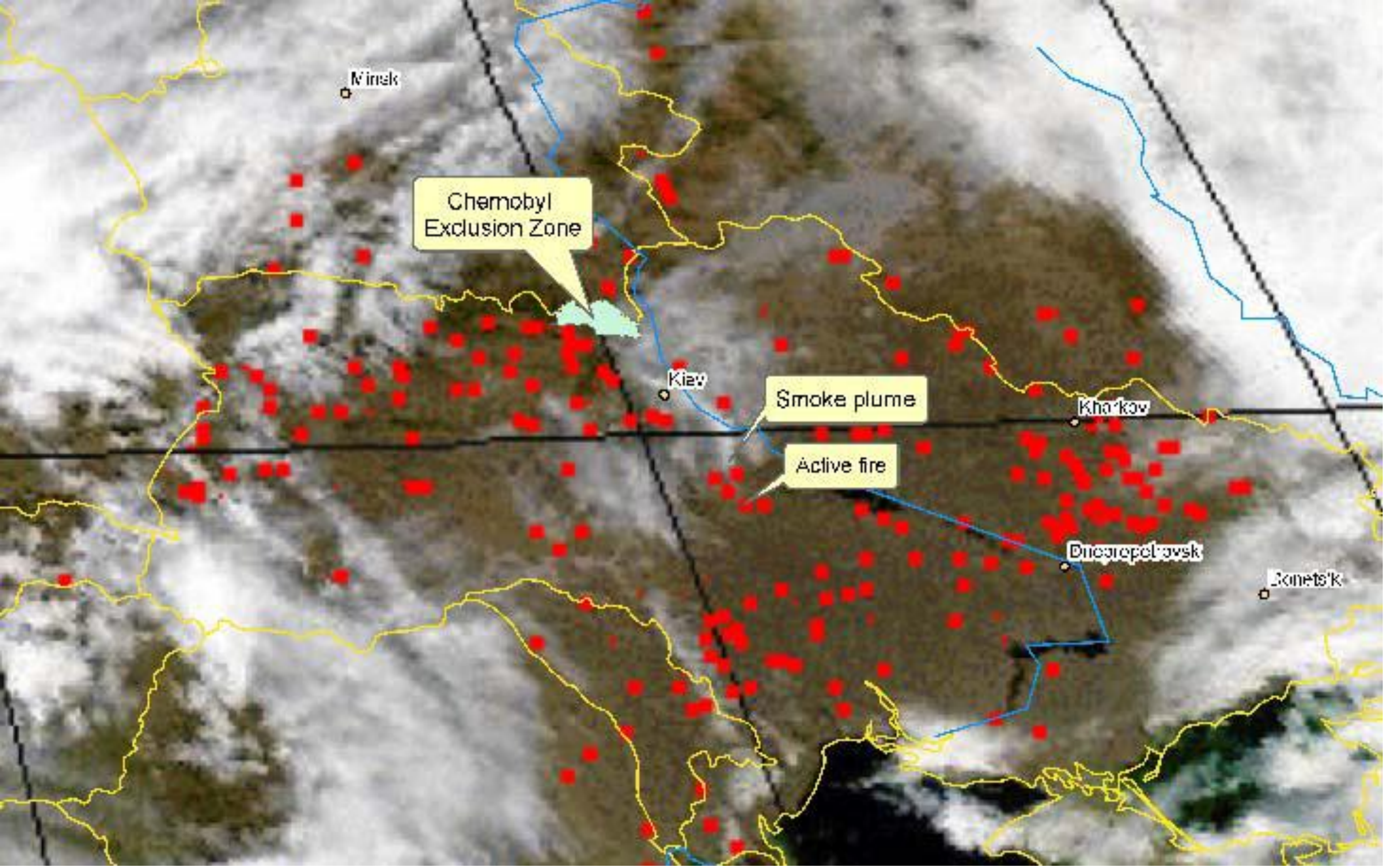
# 2021>>


1996
2021,
with management
2021,
no management

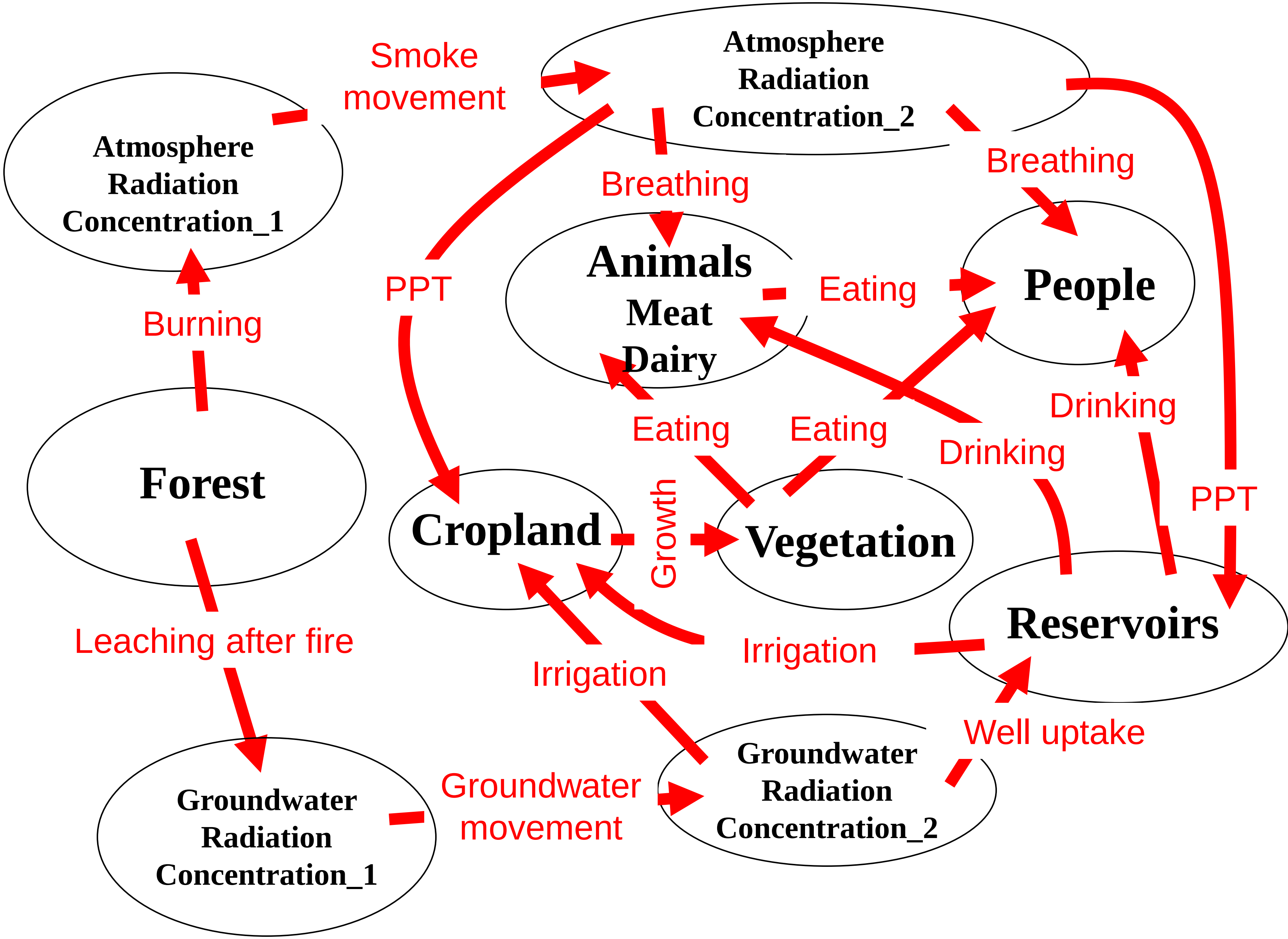
## Before thinning.

**Immediately after thinning.**

**Equipment that can do the thinning with minimal exposure of people to radioactive dust**




MODIS satellite image of fire locations (red dots) and smoke in Ukraine and its neighboring countries, April 16, 2006.



Atmosphere Radiation Concentration_1
Smoke movement
Atmosphere Radiation Concentration_2
Breathing
Breathing
PPT
Burning
Animals
Meat
Dairy
Eating
People
PPT
Forest
Eating
Eating
Drinking
Drinking
Cropland
Growth
Vegetation
Reservoirs
Leaching after fire
Irrigation
Irrigation
Well uptake
Groundwater Radiation Concentration_1
Groundwater movement
Groundwater Radiation Concentration_2

# Steps in Analysis Process

- **Prepare model in consultation with experts in various components**
- **Obtained lists of expert reviewers**
- **Sent out requests for review**
- **Receiving reviews back (requested CV, cover letter, and review)**
- **Will publish reviews with Report (perhaps amend report according to reviewers comments)**

# Wildfire in the Chernobyl Exclusion Zone: A Worst Case Scenario

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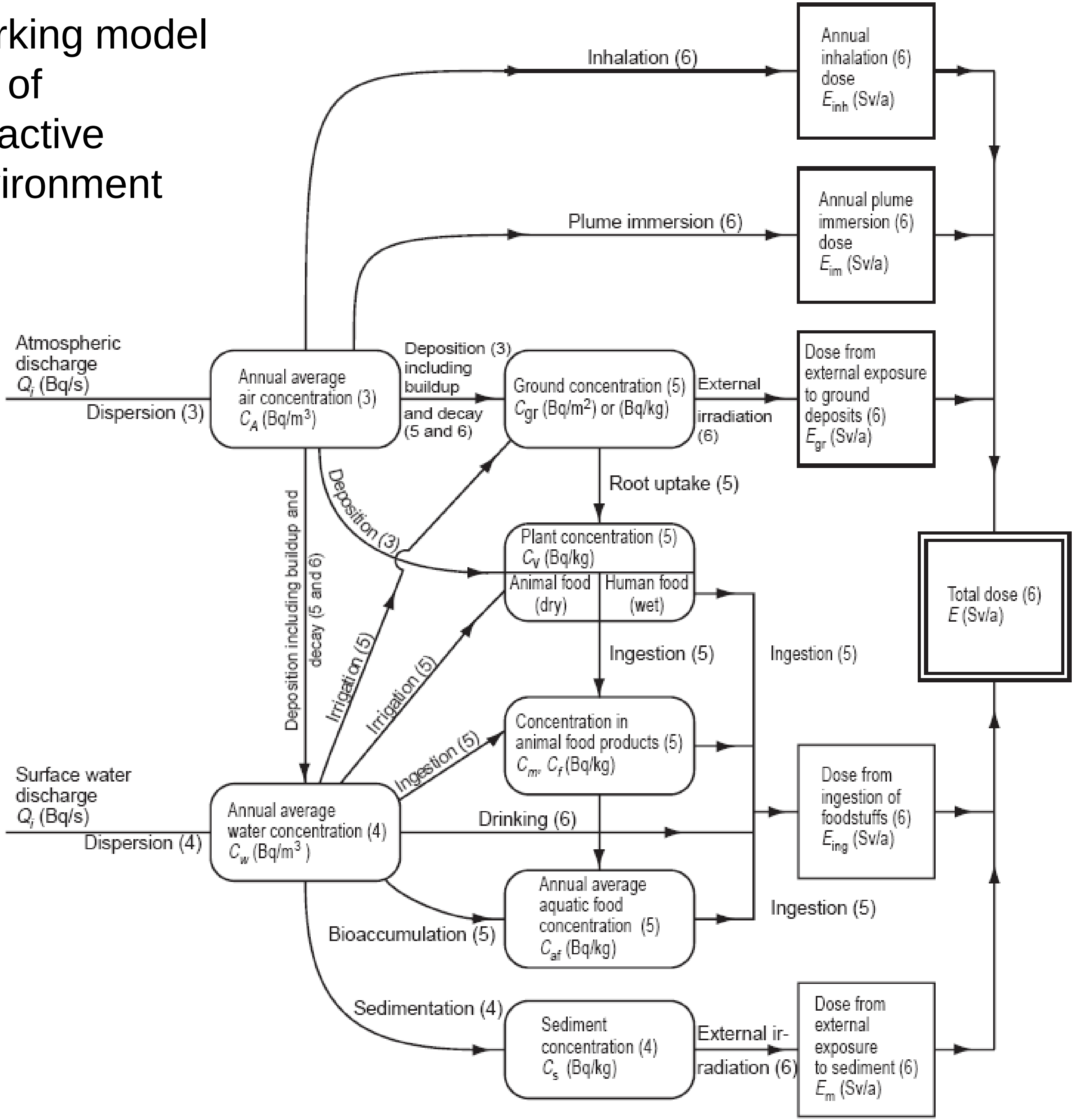
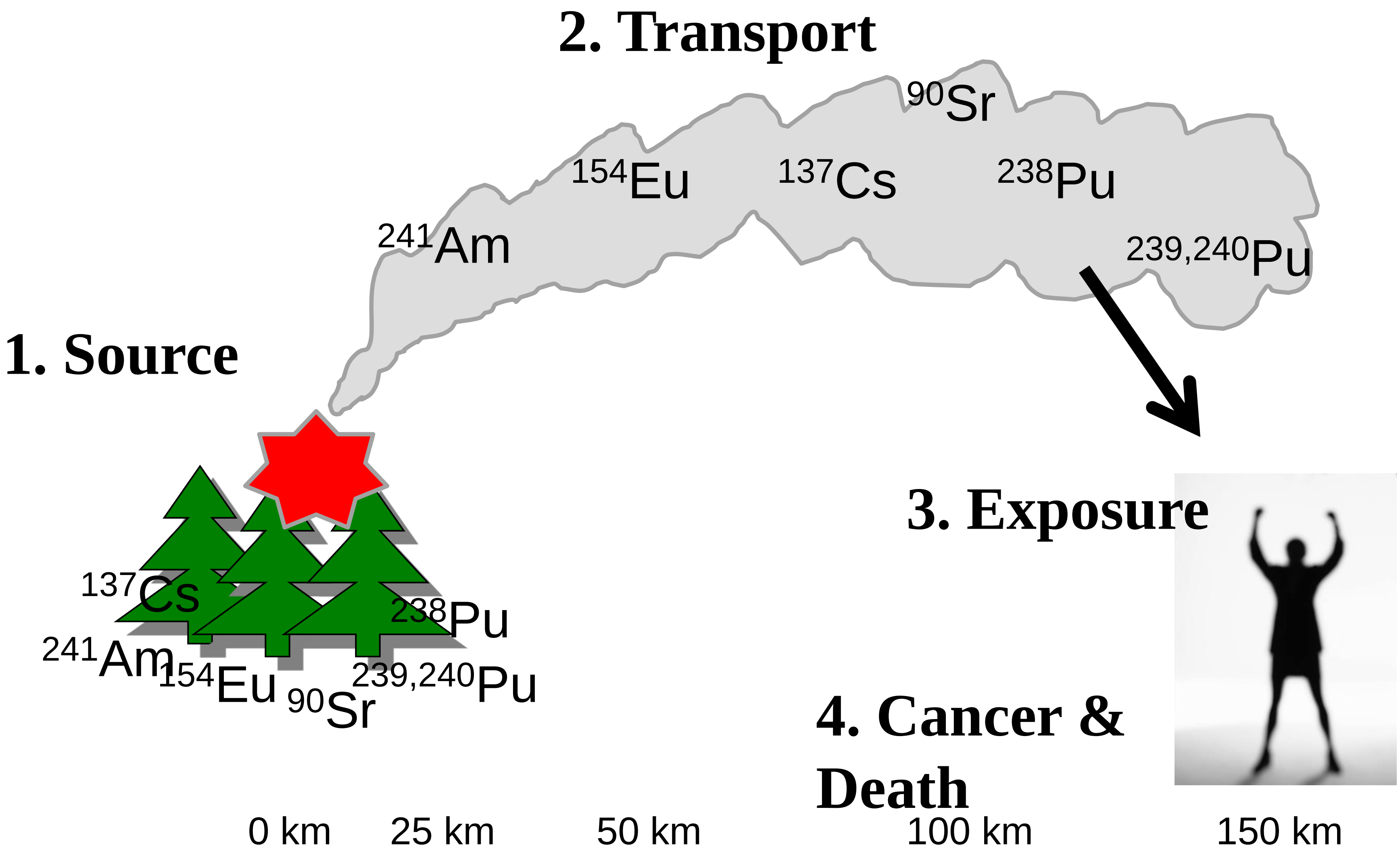
This is our current working model for assessing impacts of discharges from radioactive substances to the environment

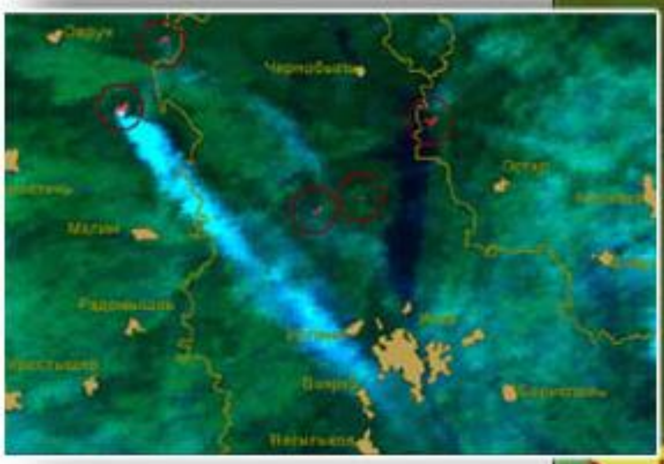


# Four Linked Models



# Схема локалізації осередків пожеж в Київській та Житомирській областях 8 травня 2003 року


Фрагмент космічного знімку
із супутника NOAA
08.05.2003, 18-30,
наданого Українським центром
менеджменту землі та ресурсів



$$C_A = \frac{P_p F Q_i}{u_a} \qquad [3]$$

where

$C_A$ is the ground level air concentration at downwind distance *x* in sector *p* ($Bq/m^3$)[1],

$P_p$ is the fraction of time per event that the wind blows toward the target population,

F is the Gaussian diffusion factor[2] appropriate for a given release height[3] and downwind distance *x* ($m^{-2}$),

Qi is the average discharge rate per event for radionuclide i (Bq/s),

$u_a$ is the geometric wind speed average at the area of release representative of the duration of the event (m/s).

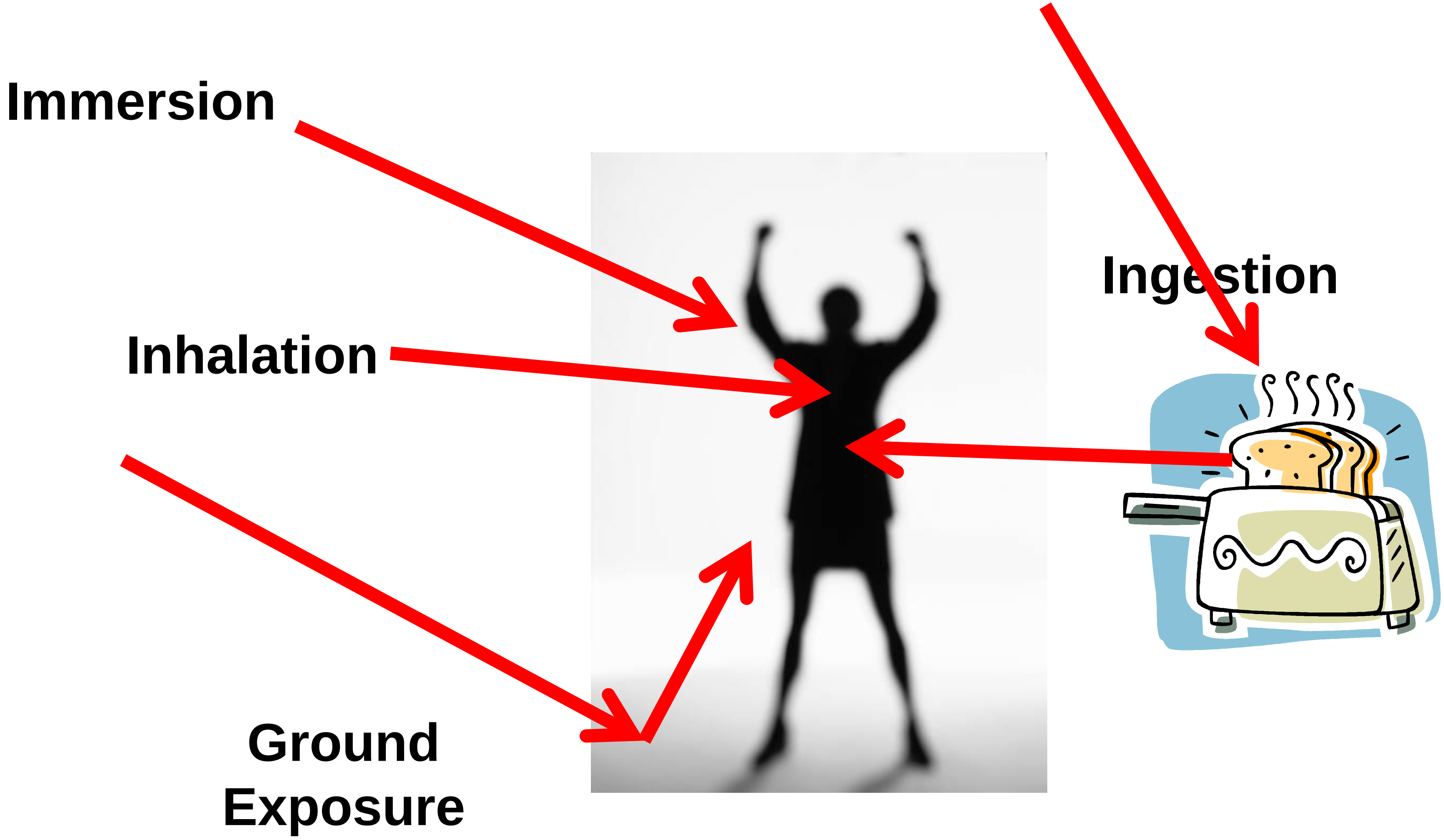

Immersion
Inhalation
Ground
Exposure
Ingestion

Table 4. Element specific transfer factors for terrestrial foods for screening purposes (IAEA 2001).

| Element | Forage (Bq/ kg plant dry weight)/ (Bq/kg soil dry weight) | Crops (Bq/ kg plant fresh weight)/ (Bq/kg soil dry weight) | Milk (d/L) | Meat (d/kg) |
|---|---|---|---|---|
| Sr | 10 | 0.3 | 0.003 | 0.01 |
| Cs | 1 | 0.04 | 0.01 | 0.05 |
| Eu | 0.1 | 2.0E-03 | 6.0E-05 | 2.0E-03 |
| Pu | 0.1 | 1.0E-03 | 3.0E-06 | 2.0E-04 |
| Am | 0.1 | 2.0E-03 | 2.0E-05 | 1.0E-04 |

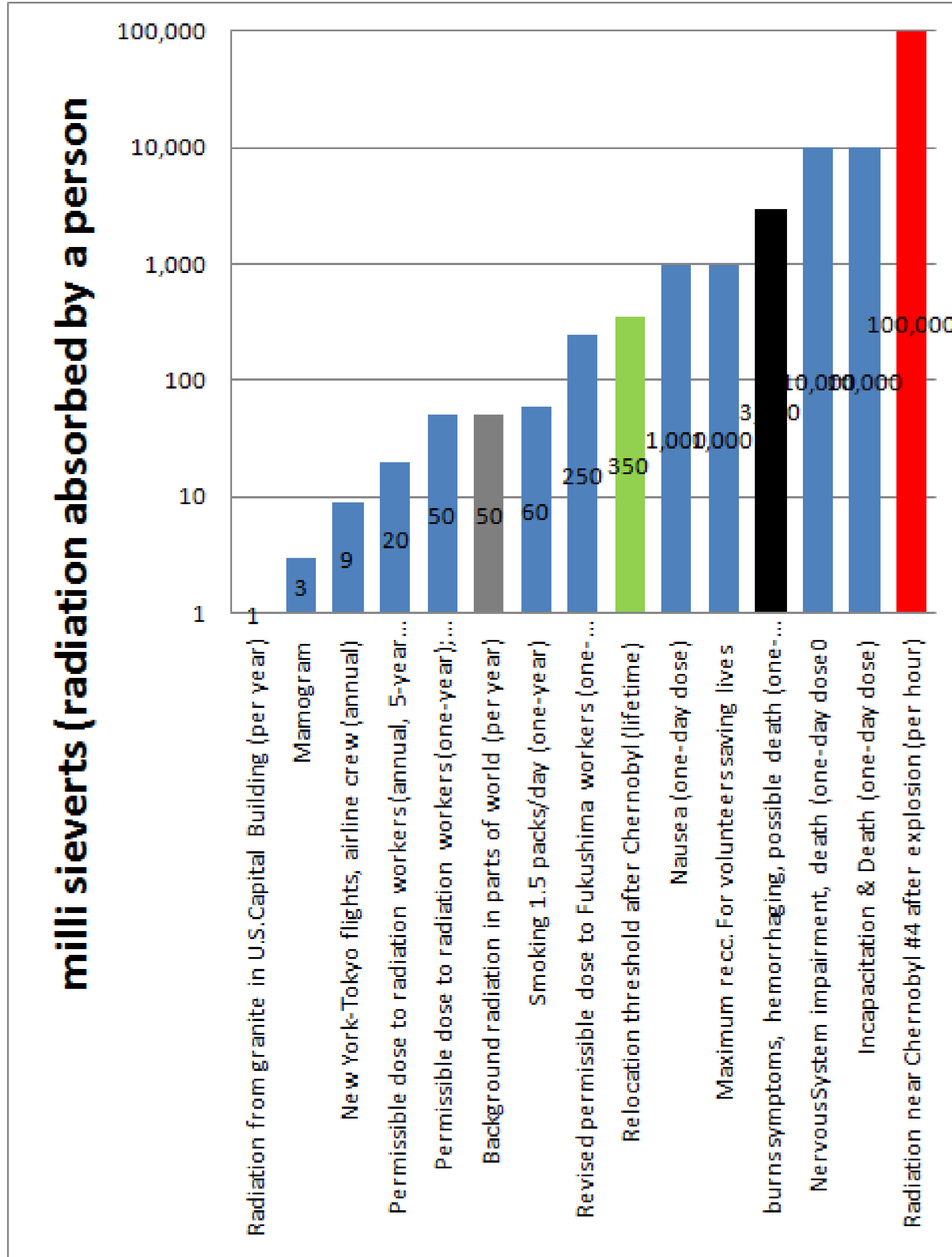
Table 2. Effective immersion, surface, inhalation, and ingestion dose coefficients for various radioisotopes (IAEA 2001).

| Radionuclide | Immersion (Sv/a per Bq/m$^3$) | Surface (Sv/a per Bq/m$^2$) | Inhalation (Sv/a per Bq/m$^3$) | | Ingestion (Sv/a per Bq/kg) | |
|---|---|---|---|---|---|---|
| | | | Adult | Infant | Adult | Infant |
| $^{90}$Sr | 3.1E-09 | 3.5E-09 | 1.6E-07 | 4.0E-07 | 2.8E-08 | 7.3E-08 |
| $^{137}$Cs | 8.7E-07 | 1.8E-08 | 4.6E-09 | 5.4E-09 | 1.3E-08 | 1.2E-08 |
| $^{154}$Eu | 2.0E-06 | 3.8E-08 | 5.3E-08 | 1.5E-07 | 2.0E-09 | 1.2E-08 |
| $^{238}$Pu | 1.7E-10 | 2.9E-11 | 4.6E-05 | 7.4E-05 | 2.3E-07 | 4.0E-07 |
| $^{239,240}$Pu | 1.6E-10 | 2.8E-11 | 5.0E-05 | 7.7E-05 | 2.5E-07 | 4.2E-07 |
| $^{241}$Am | 2.6E-08 | 8.9E-10 | 4.2E-05 | 6.9E-05 | 2.0E-07 | 3.7E-07 |

Table 8. Estimated effective dose for the critical population after a catastrophic wildfire.

| Radionuclide | Distance (km) | Immersion (Sv/a) | Ground.Exposure (Sv/a) | Inhalation (Sv/a) | | Ingestion (Sv/a) | | Total (Sv/a) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Adult | Infant | Adult | Infant | Adult | Infant |
| $^{90}Sr$ | 25 | 1.7E-09 | 6.8E-04 | 7.2E-04 | 3.0E-04 | 1.3E-02 | 2.4E-02 | 1.4E-02 | 2.5E-02 |
| | 50 | 5.8E-10 | 2.4E-04 | 2.5E-04 | 1.1E-04 | 4.5E-03 | 8.3E-03 | 5.0E-03 | 8.6E-03 |
| | 100 | 2.1E-10 | 8.5E-05 | 8.9E-05 | 3.7E-05 | 1.6E-03 | 2.9E-03 | 1.7E-03 | 3.0E-03 |
| | 150 | 1.1E-10 | 4.6E-05 | 4.9E-05 | 2.0E-05 | 8.5E-04 | 1.6E-03 | 9.5E-04 | 1.7E-03 |
| $^{137}Cs$ | 25 | 1.8E-07 | 1.4E-03 | 8.0E-06 | 1.6E-06 | 8.2E-04 | 5.2E-04 | 2.2E-03 | 1.9E-03 |
| | 50 | 6.3E-08 | 4.8E-04 | 2.8E-06 | 5.5E-07 | 2.9E-04 | 1.8E-04 | 7.7E-04 | 6.6E-04 |
| | 100 | 2.2E-08 | 1.7E-04 | 9.9E-07 | 1.9E-07 | 1.0E-04 | 6.5E-05 | 2.7E-04 | 2.3E-04 |
| | 150 | 1.2E-08 | 9.2E-05 | 5.4E-07 | 1.1E-07 | 5.5E-05 | 3.5E-05 | 1.5E-04 | 1.3E-04 |
| $^{154}Eu$ | 25 | 6.1E-10 | 4.2E-06 | 1.4E-07 | 6.4E-08 | 1.2E-09 | 2.8E-09 | 4.4E-06 | 4.3E-06 |
| | 50 | 2.2E-10 | 1.5E-06 | 4.8E-08 | 2.3E-08 | 4.1E-10 | 9.9E-10 | 1.5E-06 | 1.5E-06 |
| | 100 | 7.6E-11 | 5.3E-07 | 1.7E-08 | 8.0E-09 | 1.4E-10 | 3.5E-10 | 5.4E-07 | 5.3E-07 |
| | 150 | 4.1E-11 | 2.9E-07 | 9.2E-09 | 4.3E-09 | 7.8E-11 | 1.9E-10 | 3.0E-07 | 2.9E-07 |
| $^{238}Pu$ | 25 | 5.2E-14 | 3.2E-09 | 1.2E-04 | 3.1E-05 | 4.5E-08 | 2.9E-08 | 1.2E-04 | 3.1E-05 |
| | 50 | 1.8E-14 | 1.1E-09 | 4.1E-05 | 1.1E-05 | 1.6E-08 | 1.0E-08 | 4.1E-05 | 1.1E-05 |
| | 100 | 6.4E-15 | 4.0E-10 | 1.5E-05 | 3.9E-06 | 5.6E-09 | 3.6E-09 | 1.5E-05 | 3.9E-06 |
| | 150 | 3.5E-15 | 2.2E-10 | 7.9E-06 | 2.1E-06 | 3.0E-09 | 2.0E-09 | 7.9E-06 | 2.1E-06 |
| $^{239,240}Pu$ | 25 | 1.2E-13 | 7.4E-09 | 3.0E-04 | 7.8E-05 | 1.2E-07 | 7.3E-08 | 3.0E-04 | 7.8E-05 |
| | 50 | 4.1E-14 | 2.6E-09 | 1.1E-04 | 2.7E-05 | 4.1E-08 | 2.6E-08 | 1.1E-04 | 2.7E-05 |
| | 100 | 1.4E-14 | 9.1E-10 | 3.8E-05 | 9.6E-06 | 1.4E-08 | 9.1E-09 | 3.8E-05 | 9.6E-06 |
| | 150 | 7.8E-15 | 5.0E-10 | 2.0E-05 | 5.2E-06 | 7.9E-09 | 4.9E-09 | 2.0E-05 | 5.2E-06 |
| $^{241}Am$ | 25 | 4.4E-11 | 5.5E-07 | 6.0E-04 | 1.6E-04 | 6.6E-05 | 8.8E-05 | 6.7E-04 | 2.5E-04 |
| | 50 | 1.6E-11 | 1.9E-07 | 2.1E-04 | 5.8E-05 | 2.3E-05 | 3.1E-05 | 2.3E-04 | 8.9E-05 |
| | 100 | 5.5E-12 | 6.9E-08 | 7.4E-05 | 2.0E-05 | 8.2E-06 | 1.1E-05 | 8.3E-05 | 3.1E-05 |
| | 150 | 3.0E-12 | 3.7E-08 | 4.0E-05 | 1.1E-05 | 4.5E-06 | 5.9E-06 | 4.5E-05 | 1.7E-05 |
| Total | 25 | 1.8E-07 | 2.1E-03 | 1.7E-03 | 5.7E-04 | 1.4E-02 | 2.5E-02 | 1.7E-02 | 2.7E-02 |
| | 50 | 6.4E-08 | 7.2E-04 | 6.1E-04 | 2.1E-04 | 4.8E-03 | 8.5E-03 | 6.2E-03 | 9.4E-03 |
| | 100 | 2.2E-08 | 2.6E-04 | 2.2E-04 | 7.1E-05 | 1.7E-03 | 3.0E-03 | 2.1E-03 | 3.3E-03 |
| | 150 | 1.2E-08 | 1.4E-04 | 1.2E-04 | 3.8E-05 | 9.1E-04 | 1.6E-03 | 1.2E-03 | 1.9E-03 |

| Exposure (milliSv/year) | | Distance from Fire Center (km) | | | |
|---|---|---|---|---|---|
| | | **25** | **50** | **100** | **150** |
| Immersion | | 0.0 | 0.0 | 0.0 | 0.0 |
| Ground Exposure | | 2.1 | 0.7 | 0.3 | 0.1 |
| Inhalation | Adult | 1.7 | 0.6 | 0.2 | 0.1 |
| | Infant | 0.6 | 0.2 | 0.1 | 0.0 |
| Ingestion | Adult | 14.0 | 4.8 | 1.7 | 0.9 |
| | Infant | 25.0 | 8.5 | 3.0 | 1.6 |
| Total | Adult | 17.0 | 6.2 | 2.1 | 1.2 |
| | Infant | 27.0 | 9.4 | 3.3 | 1.9 |
| | | | | | |
| Limiting Time Outdoors | | | | | |
| | Adult | | 2.0 | milliSv/first 2 weeks | |
| | Children | | 1.0 | milliSv/first 2 weeks | |
| Evacuation done (Ukraine) | | | 50.0 | milliSv/first 2 weeks | |
| Resettlement dose (Ukraine) | | | 50.0 | milliSv/year | |
| Limiting food consumption | | | 1.0 | internal milliSv/year | |



The analysis showed that the estimated exposure of populations **<u>25 or more kilometers</u>** from the source of the fire through inhalation, immersion, and surface exposure pathways **<u>is below the critical thresholds that would require evacuations</u>** by greater than an order of magnitude.

On the other hand, the potential dosage derived from the **<u>consumption of contaminated foodstuffs could exceed acceptable levels</u>** set by the Ukrainian government—a prevented internal irradiation dose exceeding 5 mSv or a prevented average annual dose exceeding 1 mSv. For both adults and infants these levels could be almost met or exceeded by consuming food produced at distances as great as 150 km from the center of the CEZ. These highest levels of contamination would occur directly along the trace of the plume. As one moved away from the trace, contamination levels would decline, so the actual amount of agricultural land that would need to be taken out of production would be limited.

From an epidemiological standpoint, the worst case scenario would be if the trace of the plume intersected with a major population center, such as Kiev. If we assume:

1) the entire population of Kiev **(2.7 million)** was exposed to the trace;

2) the population had a sex ratio of 1:1 at the time of the fire; and

3) the average age of the population was 20 at the time of the fire; and

4) residents successfully avoided exposure through ingestion;

then we would expect **168 additional cancers** to be diagnosed over the lifetime of the residents based on the exposure during the first year after the fire. We would expect **81 additional cancer deaths** to occur.

# Steps in Analysis Process

- Prepare model in consultation with experts in various components
- Obtained lists of expert reviewers
- Sent out requests for review
- Receiving reviews back (requested CV, cover letter, and review)
- Will publish reviews with Report (perhaps amend report according to reviewers comments)
- (May consider submission to journal)