**Abstract 33: Poster presentation**

# Definition and quantification of vulnerable areas in northern Norway


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## Introduction

In Norway, 15% of all lamb meat, 42% of goat milk, 11% of cow milk and 60% of the reindeer meat is produced in the three most northern counties as shown in Figure 1. Agricultural practice in this area utilises, to large extent, uncultivated areas for production of meat and milk. Compared to cultivated land use systems, uncultivated ecosystems show a relatively high radiocaesium transfer from soil via plant to animal products. As a result, agriculture in northern Norway is regarded as vulnerable with respect to radiocaesium deposition. The concepts of *action load* and *flux* are used for the further identification of areas that will contribute to elevated levels of radiocaesium in food products. Knowledge about the transfer of radiocaesium from soil to food products, in combination with spatial data on soil texture classes, land use, production statistics and grazing locations is used in these two approaches for radiocaesium vulnerability. Identification of vulnerable areas are of great value in emergency preparedness planning and in the allocation of resources for future radioecological studies.

## Method

Vulnerable ecosystems with deposition of $^{137}Cs$ are defined in this paper using the following concepts: *action load* and *flux*. Action load is the $^{137}Cs$ deposition that will lead to an activity concentration in a product equal to the defined intervention level for that product which are, 600 $Bq \cdot kg^{-1}$ for lamb meat, 370 $Bq \cdot kg^{-1}$ for milk and 3000 $Bq \cdot kg^{-1}$ for reindeer meat. The second concept, the $^{137}Cs$ flux, is the amount of $^{137}Cs$ ($Bq \cdot year^{-1}$) that is removed from an area through grazing of animals used for the production of meat and milk in that area.

In both concepts, the soil information is of primary importance. The soil map of Norway is based on mapping units/polygon (SMU) which is again based on the occurrence of one to maximal six soil type units (STU) having unique soil properties. To model the potential transfer of $^{137}Cs$ from these soils the STUs are divided into three texture classes: sand, loam and peat and the aggregated transfer coefficients ($T_{ag}$) and TC have been applied, as shown in Table 1. The $T_{ag}$ and TC value for each soil polygon (SMU) is weighted with regard to the proportional occurrence of the texture classes in each unit. The applied coefficients are valid from 5 to 10 years after fallout. Assessments in other time periods need to be time corrected. The action load is calculated by dividing the intervention level by the $T_{ag}$ and TC related to a specific soil type.

Note that the $T_{ag}$ value for reindeer is not related to soil texture only the seasonal change in diet related to summer and winter grazing areas. The modelled transfer of $^{137}Cs$ from vegetation to cow milk uses $F_m$, of 0.008 $d \cdot kg^{-1}$ (IAEA, 1994) and to goat milk, $F_m$, is 0.1 $d \cdot kg^{-1}$, (Garmo *et. al*., 1988). The grazing area for milk producing cows is mainly on cultivated pastures. It is assumed that grass based fodder is produced locally with an intake of seven kilograms grass (dry weight) and that concentrates are imported from non-contaminated areas. Goats and sheep graze on largely or completely uncultivated pastures, hereafter termed natural pastures. The daily intake of vegetation by goats is circa one tenth of that by cows.

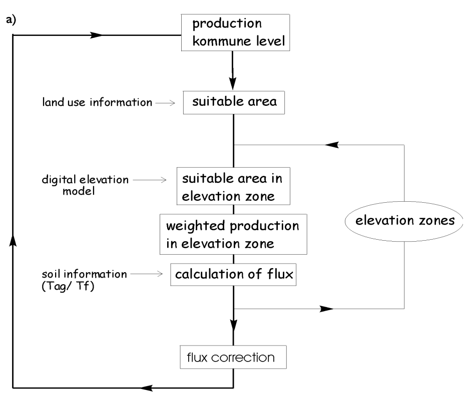
**Table 1** TC and $T_{ag}$ values ($m^2/kg$) used in the model.

| $T_{ag}$ | Sand | Loam | Organic | Winter | Summer | Reference |
|---|---|---|---|---|---|---|
| Lamb ($T_{ag}$) | 0.008[1)] | 0.002[1)] | 0.04 | | | Hove *et al.* 1994 |
| Grass cultivated pasture (cow milk) TC | 0.01 | 0.005 | 0.1 | | | Eriksson, 1994 |
| Grass natural pasture (goat milk) TC | 0.02 | 0.01 | 0.2 | | | Eriksson, 1994 |
| Reindeer ($T_{ag}$) | | | | 0.76 | 0.12 | Åhman & Åhman 1994 |

1) Estimated by using relative differences in transfer from soil to grass as an indicator

Activity concentrations in the different products multiplied by the produced amount give the flux of $^{137}Cs$ per year. The variation in fluxes is estimated by using a number of spatial varying parameters. Soil properties, production statistics, land use information and assumed information on grazing locations are combined in a model that is implemented in a geographic information system or GIS. The scale of the soil map is 1:100,000,000 and the landuse and topographic maps are 1:125,000. Flowcharts of two GIS models are given below in Figure 2a and 2b. The GIS model is run for a release scenario that causes a uniform $^{137}Cs$ deposition of 10 $kBq \cdot m^{-2}$.

The areas that are classified in the landuse map as cultivated pastures are used for the cow milk production in the calculation of fluxes. Sheep meat and goat milk production fluxes are based on the use of natural pastures as grazing areas; cultivated, glaciers, and urban areas that are present in the land use map could therefore be excluded as grazing areas in the calculation. The grazing areas for sheep and goat are defined in greater detail by using four elevation zones: 0-250, 250-500, 500-1000 and 1000-1500 metres, with areas higher than 1500 metres assumed to be ungrazed and also therefore excluded from the calculations. It is further assumed that there is a higher probability for sheep and goats to graze in the lower elevation zones than in the higher zones. The latter is based on the assumption that grazing is possible in the higher zones only during a short period in the year.



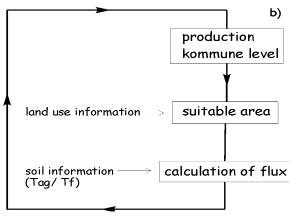




Figure 2a.: flowchart of model used for calculation of flux through lamb meat and goat milk production.
Figure 2b.:flowchart of model for the calculation of flux through cow milk production.

### Uncertainty and reliability

The unexplained variation in parameters such as (aggregated) transfer coefficients and grazing habits produces an error in the calculations of both the action loads and fluxes of $^{137}Cs$. Furthermore the confidence and accuracy in the GIS maps contribute to the error in the final output of the model. The soil type units have different confidence due to differences accuracy in the soil survey. The confidence was originally ranked as high, middle and low. In order to weight the soil mapping units, the confidence levels have been given numeric values 3, 2, and 1, respectively. The resulting map can be seen in Figure 3.

The landuse map is a key map in linking production figures to areas used in the modelling of fluxes. It is known that the location and size of areas used for the production of lamb meat and cow and goat milk have associated errors. The estimated error in the position of boundaries between landuse classes is 50 to maximal 100 metres. The confidence in the map is visualised by means of a variety index map. The map was created by producing a raster map of 100 × 100 metre grid cells. A GIS technique called *spatial diversity* (Burrough and McDonell, 1998) is then applied to calculate the variation in landuse classes. In this process a window of 3 × 3 grid cells region is moved over the raster map. When all neighbouring grid cells to a selected cell in the region show the same landuse, the value will be one and the local spatial variation is minimised and the confidence level is maximised. On the other hand, when all neighbouring grid cells show a different landuse class, the local spatial variation is maximal and the confidence in landuse information will be minimal.

**Results and Preliminary Conclusions**

The action load maps (Figure 1a-c) reflect the diversity in the soil map. The potential vulnerability for radioactive contamination of the three products decreases in the following order: lamb meat >> goat milk > cow milk. It is known that the radiocaesium uptake by sheep can be 75-85% higher in years with high abundance of fungi (Mehli & Skuterud, 1998). transfer from soil to cow and goat milk is based on intake of vegetation with no fungi. The $T_{ag}$ for sheep are based on natural pastures which contain moderate abundance of fungi. This may be one of the explanations for the differences in action load between lamb meat and cow and goat milk The grazing areas for reindeer in wintertime (not shown) will have the lowest action load in the maps, but in summer, the action load will be higher and in the same range as for lamb. The $T_{ag}$ and TC are mainly derived from Chernobyl fallout data from southern Norway and mid-Sweden. Climatic and topographic conditions may be different in the three northern Norwegian counties. The action load maps identify potentially vulnerable areas, however if no production is taking place they will obviously not be significant contributors to radiocaesium in foodstuff. The flux maps show highest fluxes for lamb meat and goat milk in areas where soils are of peaty or sandy type, and in municipalities with high production.

The confidence map (Figure 4a) shows areas having higher and lower confidence in the described soil properties. The dark areas correspond to the less surveyed areas and the less investigated soil properties. This means effectively that uncertainty in these areas is also highest when it comes to the modelling of action load and flux. The variation index map for landuse (Figure 4b) shows light coloured areas corresponding with low variation, and thus high confidence, while dark colours shows high variation and low confidence. This is in contrast with the low confidence in soil mapping for these areas, which are mainly uncultivated areas.

Both action load and flux maps could be used in a decision support system for planning in case of emergencies. The concept can be used to give a first quick overview of the likely situation following radiocaesium deposition. When more detailed information is available this concept can be applied on municipally level to improve local preparedness planning.

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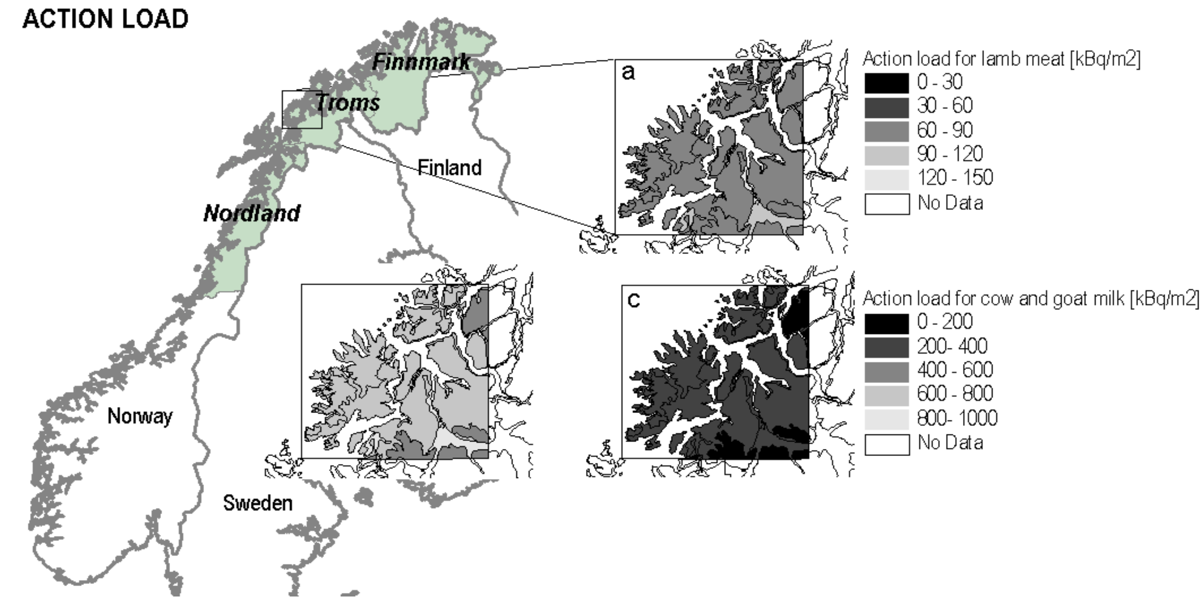


*Figure 1* *Map over Norway showing areas used for action loads: a) lamb; b)cow and c) goat*

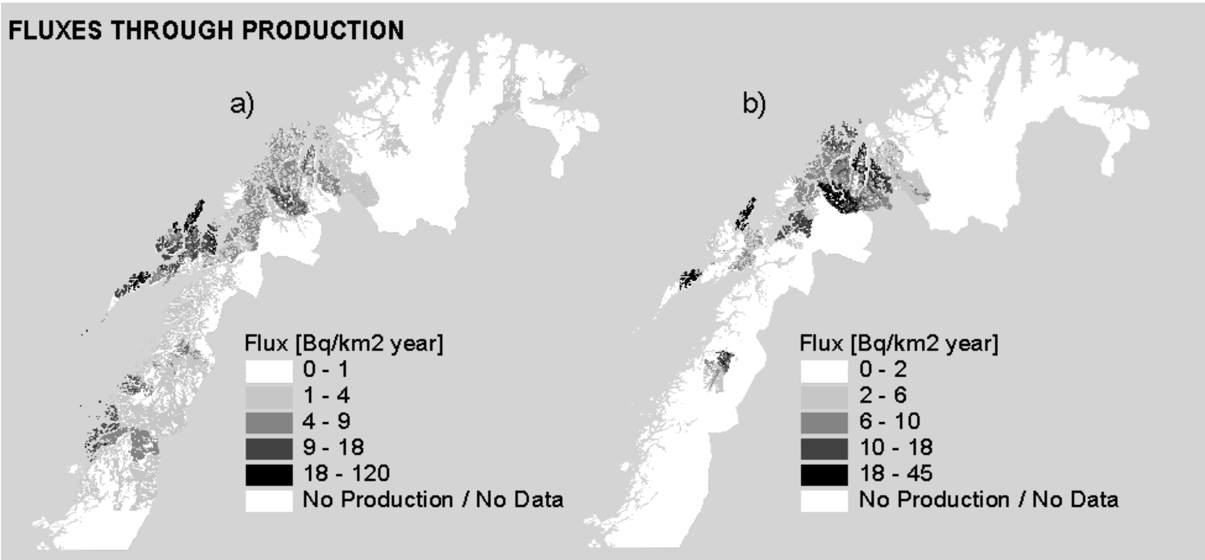


***Figure 3a)*** *Flux through lamb meat production; b) Flux through goat milk production*

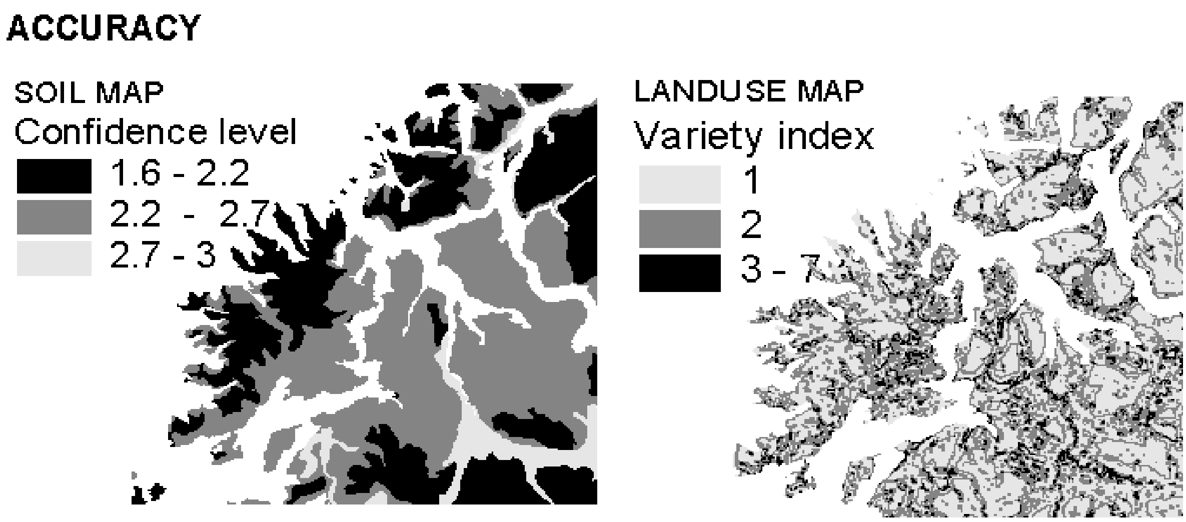


**Figure 4a)** Confidence levels for part of the soil map**;** **b)** Variety indexes for part of the landuse map