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Theme 1. Grassland resources
Sub-theme 1.2. Global monitoring of grasslands

Modeling of the Fukushima Daiichi nuclear power plant derived radioactive cesium dynamics in grazing grassland

Mikinori Tsuiki[1]*, Moe Yamashita[1], Yasuko Togamura[2], Fumiaki Akiyama[2], Kiyoshi Hirano[2], Daigo Yamada[2], Yasuyuki Ide[2] and Takeshi Shibuya[2]
[1]Iwate University, Morioka, Japan
[2]NARO Institute of Livestock and Grassland Science, Nasushiobara, Japan
Corresponding author e-mail: tsuiki@iwate-u.ac.jp

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Introduction

The damage to the Fukushima Daiichi Nuclear Power Plant incurred following the Great East Japan Earthquake and tsunami on March 11, 2011 resulted in serious radioactive pollution of Eastern Japan. In some grasslands of this area, radioactive cesium (Cs) content of grasses exceeded the provisional safety standard for use as feed for dairy and beef cattle of 100 Bq kg^{-1} fresh weight, and the livestock industry has been seriously affected in numerous ways: needing to dispose of polluted forage, grazing prohibitions, declines in beef prices, suspensions of shipping beef to market, and blanket testing of beef cattle (Manabe *et al*., 2013). The spatial distribution of radioactive Cs in grasslands was complex in various scales (Tsuiki and Maeda, 2012a; 2012b). So it is difficult to estimate actual pollution level in grassland ecosystems. The transfer of radioactive Cs from soil to plant is affected by soil soluble potassium (K) concentration, pH, clay and organic matter contents (Absalom et al., 2001; Tsuiki *et al*., 2013). The radioactive Cs dynamics in soil-plant-animal system is complex and modeling is necessary to clarify the relationships. In this study, a model of radioactive Cs dynamics in *Zoysia japonica* Steud. dominated grazing grassland was developed to predict radioactive Cs concentration of grass and grazing cattle.

Materials and Methods

Zoysia japonica Steud. dominated grazing grassland in Tochigi Prefecture, Japan (36° 55' 19.42 N, 139° 57' 12.85 E) was investigated from 2011 to 2014. Four breeding cows were grazed in 1.5 hectare pasture. Two kinds of radioactive Cs, ^{137}Cs (half life: 30.17 years) and ^{134}Cs (half life: 2.06 years), were released from the nuclear power plant. ^{137}Cs concentration in vegetation, litter, feces and urine was measured once a month from May to October. Cows were slaughtered after grazing and ^{137}Cs concentration in beef was measured. System dynamics approach was used for modeling. Dynamic flow of ^{137}Cs in *Zoysia japonica* dominated grazing grassland was simulated (Fig. 1). Soil unadsorped ^{137}Cs, soil adsorped ^{137}Cs, vegetation ^{137}Cs, litter ^{137}Cs, cattle ^{137}Cs, feces ^{137}Cs and urine ^{137}Cs were selected as level. The flow from soil unadsorped ^{137}Cs to soil adsorped ^{137}Cs was affected by radiocesium interception potential (RIP). RIP was calculated by partition coefficient (K_D) and K in soil solution.

$$RIP = K_D * K \text{ in soil solution} \quad (1)$$

K_D was defined as the ratio of quantity of ^{137}Cs sorbed per unit mass of frayed edge sites in soil to the equilibrium concentration of contaminant in soil solution.

$$K_D = (^{137}\text{Cs adsorped to frayed edge sites of micaceous minerals in soil}) / (^{137}\text{Cs in soil solution}) \quad (2)$$

The flow from soil unadsorped ^{137}Cs to vegetation ^{137}Cs was affected by soil exchangeable K content. The flow from feces and litter ^{137}Cs to unadsorped ^{137}Cs was affected by air temperature. The growth of vegetation was decided by observed data with table function. The unit of levels was Bq m^{-1} and the unit of simulation time was day.

Results and Discussion

Observed and simulated results of ^{137}Cs concentration of vegetation, feces, urine and beef were shown in Fig. 2. As fallout ^{137}Cs was deposited on the surface of vegetation just after the accident, ^{137}Cs concentration of vegetation and litter in 2011 exceeded 100,000 Bq kg^{-1}. Although ^{137}Cs concentration of vegetation went down year by year since 2012, its decline was quite slow. The range of ^{137}Cs concentration of vegetation was 400~1600 Bq kg^{-1}. ^{137}Cs concentration of feces was higher than vegetation. ^{137}Cs concentration of beef was 196 Bq kg^{-1} in 2013 and 153 Bq kg^{-1} in 2014.

Simulated results of yearly changes of ^{137}Cs concentration in vegetation, beef, feces and urine agreed with observed results. This indicates that the model may be applied to prediction of ^{137}Cs effects for following few decades. On the other hand, simulated results of seasonal changes did not necessarily agree with observed results. Seasonal changes of plant growth rate, nutrient uptake from root and decomposition of litter and feces affect seasonal dynamics of ^{137}Cs concentrations. Further improvement is necessary to predict the dynamics of radioactive Cs in grassland ecosystems

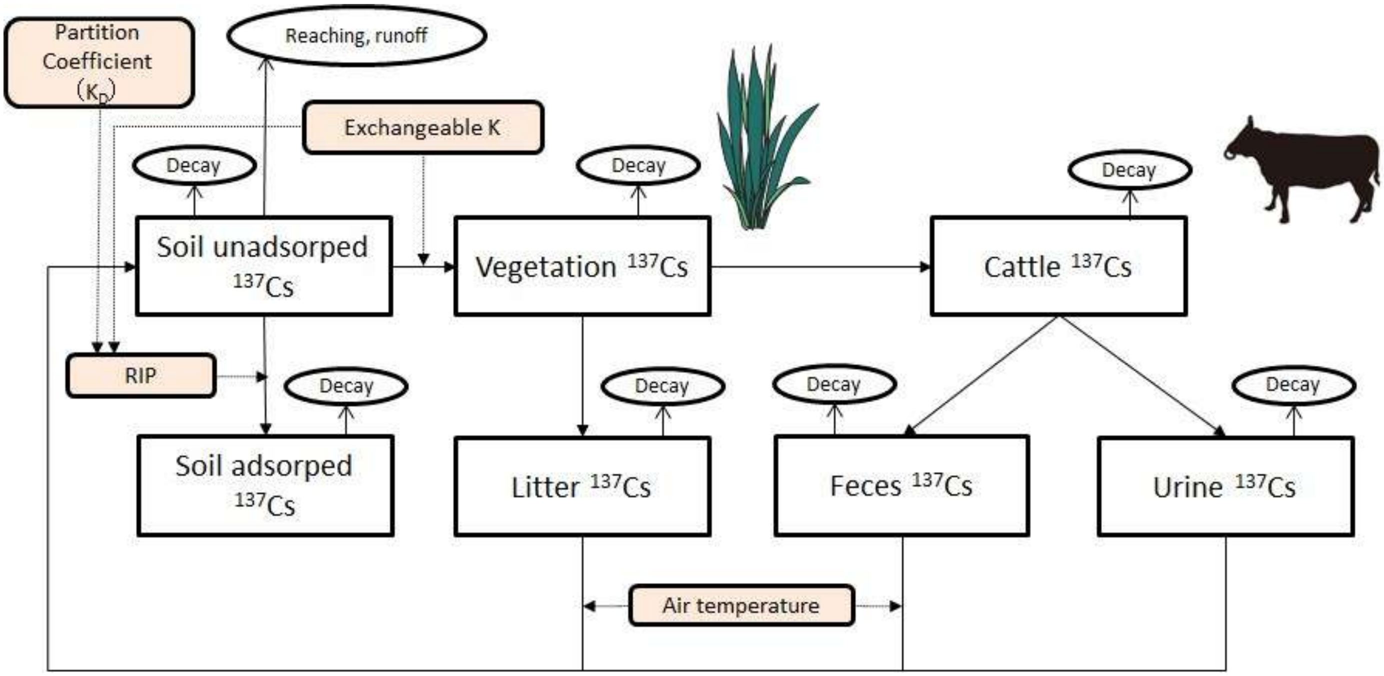

Fig. 1: The ^{137}Cs flow in *Zoysia* type grazing grassland

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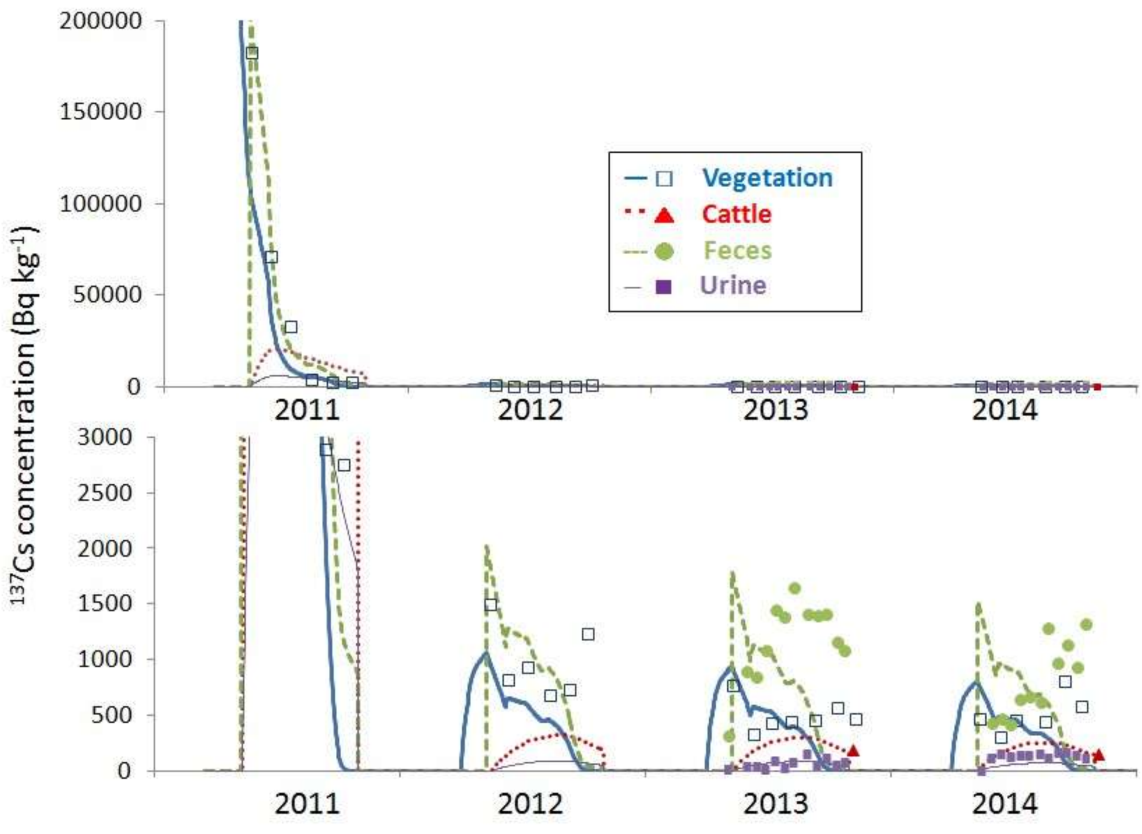

Fig. 2: Simulation results of ^{137}Cs dynamics in grazing grassland (March 15, 2011～December 31, 2014)

Conclusion

A model of radioactive Cs dynamics in *Zoysia japonica* dominated grazing grassland was developed to predict radioactive Cs concentration of grass and grazing cattle. Soil unadsorped ^{137}Cs, soil adsorped ^{137}Cs, vegetation ^{137}Cs, litter ^{137}Cs, cattle ^{137}Cs, feces ^{137}Cs and urine ^{137}Cs were selected as Level variables. The flow from soil unadsorped ^{137}Cs to soil adsorped ^{137}Cs was affected by RIP (radiocesium interception potential). RIP was calculated by partition coefficient (K_D) and soil exchangeable K content. The flow from soil unadsorped ^{137}Cs to vegetation ^{137}Cs was affected by soil exchangeable K content. Yearly changes of ^{137}Cs content could be estimated by the model. But seasonal changes did not agree with observed results. Further improvement is necessary to predict the dynamics of radioactive Cs in grassland ecosystems.

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