ヨーロッパにおける新石器時代移行への農耕民族と狩猟・採集民族の現象数理学的考察

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Abstract

Model-aided understanding of farmers and hunter-gatherers in the Neolithic transition in Europe

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Neolithic transition is one of the most significant single developments of human history that consists in a demographic shift from hunter-gatherers to farmers. The Neolithic transition in Europe began the spread of early farming through interactions between farmers and hunter-gatherers about 10,000 years back. Radiocarbon dating was performed by archeologists to gather quantitative data related to the spread of agriculture in Europe. Such an anthropological indication demonstrates that early farming was started to spread over the Europe from a place named Jericho, which was treated as the center of Neolithic transition. It also suggests that early farming advances with almost a constant velocity, which was estimated as 1.0 ± 0.2 km/ year. To understand this evidence theoretically, many attempts have been progressed through mathematical modeling. However, most of the existing reaction-diffusion models of Fisher-KPP type are not able to predict the expanding velocity of agriculture in Europe. More precisely, the predicted velocity is faster than the observed one.

We focus on the question: Is there any mechanism for which the expanding velocity of farmers becomes slow down? To answer this question, we claim that "effect of farming technology could be one of the possibilities to make the expanding velocity slow down". For this purpose, we propose a three-component reaction-diffusion system including farming technology effect with two different characteristics of farmers (sedentary and migratory ones) and hunter-gatherers. Numerical simulation demonstrates that if the effect is not so strong, expanding patterns of farmers in $\mathbb{R}^2$ becomes radially symmetric which suggests that expanding velocity can be approximated by the minimal velocity of one-dimensional traveling wave solutions. We use a numerical approach to obtain traveling wave solutions by solving an initial-boundary value problem, which is not a standard shooting method. The minimal velocity of traveling wave solutions characterizes the expanding velocity of farmers. Finally, we could say that expanding velocity of farmers becomes slow down when farming technology is developed. However, when the effect is rather strong, expanding patterns of farmers lose its radial symmetry, in other words, when farming technology is suitably developed that indicates the occurrence of planar instability of traveling wave solutions. Numerical investigations reveal that the planar traveling wave solution with minimal velocity is destabilized when farming technology improves suitably. This is one of the interesting phenomena in our system. In order to study these phenomena, we introduce a two-component system with degenerate, nonlinear diffusion as a singular limit system instead of our original system.

Keywords:

Neolithic transition; Three-component reaction-diffusion systems; Farming technology; Traveling wave solutions; Spreading velocity; Planar instability; Singular limit system.