CHAPTER 8

Demographic Decisions and Cascading Consequences

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8.1 Introduction

Global human population has been increasing rapidly in the last several decades from 2.5 billion in 1950 (U.S. Census Bureau, 2009) to more than 7.2 billion in 2014 (Population Reference Bureau, 2014). The vast majority of such population growth has taken place in developing countries. The global decline in mortality rate along with the high (although declining) fertility rates in developing countries may explain this rapid population growth (Bilsborrow et al., 2001, The World Bank, 2015). Such high population size and growth have directly or indirectly caused many socioeconomic and environmental problems across local to global scales (Cohen, 2003, de Sherbinin et al., 2007, Vitousek, 1994). These problems include biodiversity loss, ecosystem degradation, habitat fragmentation, hunger, and social unrest. They are prevalent in many parts of the world, even in "protected areas" (Curran et al., 2004, Liu et al., 2001). The population issue has gained attention at least as far back as the famous book *An Essay on the Principle of Population* (Malthus, 1798). Over the last several decades, many calls to curb the population explosion have been heard (e.g., Ehrlich, 1968, Ehrlich and Ehrlich, 2006, Meadows et al., 1972, O'Neill et al., 2010).

Many scholars have proposed models or theories regarding demographic dynamics (e.g., changes to birth and death rates; see Bilsborrow, 2002, Boserup, 2005) and their subsequent environmental consequences. For example, the vicious circle model (VCM; Brown, 2003, Marcoux, 1999) posits positive feedback loops among resource depletion, growing poverty, and high fertility. The widely cited IPAT model states that the environmental impacts (I) are the product of population (P), affluence (A), and technology (T) (Ehrlich and Holdren, 1972). Some scholars hold more optimistic views toward such acute human–environment crises in light of many mediating factors. Examples include agricultural intensification, technological advancement, institutional or cultural adaptation, and market substitution (Boserup, 1965, Simon, 1990).

There are many models and theories concerning population–environment relationships (e.g., Bilsborrow, 2002, Bilsborrow et al., 2001, Boserup, 1965, de Sherbinin et al., 2008, O'Neill et al., 2010). Many of these approaches rely on aggregated population measures (size, growth rate, fertility, etc.). Increasingly, other dimensions of demographics have been shown to deserve more attention. Examples include household numbers, demographic compositional measures (e.g., age and gender structure), and individual-level demographic decisions. For instance, Liu et al. (2003) found that in many parts of the world, even if population size declined, the number of households increased substantially. The resultant smaller households tended to have lower resource-use efficiency and posed serious threats to the environment. This thread of microlevel (primarily household) research in coupled human and natural systems (CHANS) is found in a large number of empirical studies (for a review on this topic, see de Sherbinin et al., 2007). Furthermore, it is considered essential to incorporate gender and age

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shown in Section 8.4, different demographic decisions may cause major habitat change in either deciduous or coniferous forests. Coniferous forests, located in higher elevations compared to deciduous forests, are closer to the upper elevational boundary of panda habitat. If resources are limited, less priority can be placed on conserving habitat areas of coniferous forests due to their longer distances from residential areas and relative inaccessibility for local residents. Also worthy of mention is that individual-level demographic decisions, especially those less researched, such as marriage timing and birth interval, deserve more attention as they have long-term significant impacts on population and environmental dynamics. In addition, the complexity features in coupled systems may warrant data collection and analysis over long time frames (to account for time lags and feedback loops) and large geographic extents (to include spatial heterogeneity). Empirical research over several decades or larger spatial extents would in most instances be difficult, but modeling would be feasible.

8.6 Summary

Human populations in many places are undergoing demographic transitions involving complex shifts in marriage timing, fertility, mortality, and migration. But the interactions between individual characteristics (e.g., age and demographic decisions such as marriage) and the natural environment are not well understood. To fill this knowledge gap, we used an agent-based model to simulate interactions between demographic properties of individual households and environmental change in Wolong Nature Reserve in China, which has undergone profound shifts in demographics. Demographic characteristics such as time interval between marriage and age at first birth were shown to affect population size, household number, and fuelwood collection behaviors, which in turn impacted forests and panda habitat. Complex patterns arose from these demographic parameters such as non-linearities and thresholds, feedbacks, legacy effects, time lags, heterogeneity, and resilience. For example, when the time interval between marriage and first birth increased from one year to 11 years, population size responded quickly in about 3–5 years. But it took nearly 40–50 years for panda habitat to show less degradation with the increase in time interval between marriage and first birth. An example of heterogeneity can be seen in our simulation results showing improvements in coniferous forests far from households 50 years after population reduction. In contrast, declines were seen in deciduous forests closer to households after population expansion. Our work demonstrates the importance of considering and modeling individual-level differences and demographic decisions in coupled human and natural systems over long-term time frames.

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