Chapter 6
Effects of Global Household Proliferation on Ecosystem Services

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Abstract Population sizes and growth rates are two major factors used by ecologists in assessing human impacts on ecosystems and landscapes. However, the numbers of households have been increasing much faster than population sizes. As households are basic socioeconomic units (e.g., in consumption of ecosystem services) and key components of coupled human and natural systems, household proliferation has important implications for ecosystem services. On one hand, more households consume more ecosystem services. On the other hand, more households have more impacts on the supply of ecosystem services. So far, most impacts have been negative. As a result, ecosystem services have continued to degrade. It is important to use ecosystem services more efficiently, turn households from consumers to producers of ecosystem services, and incorporate household proliferation into ecosystem service research and management.

Keywords Households · Population · Ecosystem services · Impact · Human activities · Landscape · Coupled human and natural systems · Policy · Management · Housing

6.1 Introduction

Ecosystems and landscapes are coupled human and natural systems (Liu et al. 2007), in which humans interact with natural components. In the past, human population sizes and growth rates were usually used by ecologists in studying relationships between humans and natural systems. However, household numbers

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and growth rates were largely overlooked even though households are basic socioeconomic units and are key components of coupled human and natural systems.

Households are major consumers of ecosystem services and play important roles in ecological change. For example, a basic need for each household is a housing unit (e.g., house, apartment), which drives land-use and land-cover changes and subsequently changes in ecosystem services. The household sector is the major consumer of energy in China (Lu et al. 2007). Direct and indirect energy consumption by U.S. households makes up 85 % of national energy use (Bin and Dowlatabadi 2005) and U.S. households emit about 38 % of national carbon emissions through their direct actions (Dietz et al. 2009). On the other hand, households in many areas are vulnerable to threats induced by land change and other types of environmental change (McGranahan et al. 2007). To restore and protect ecosystem services, many countries have implemented payments for ecosystem services (Daily and Matson 2008; Liu et al. 2008). Many of these programs, such as the Grain-to-Green Program of China (Liu et al. 2008) and the Silvopastoral Project in Colombia, Costa Rica, and Nicaragua (Pagiola et al. 2007), occur at the household level.

Given the importance of households, in this chapter we first illustrate global household proliferation (growth in household numbers). Then, we discuss effects of household proliferation on ecosystem services. And finally, we provide suggestions for ecosystem service research and management in the context of household proliferation.

6.2 Global Household Proliferation

Among the 172 countries with relevant data (United Nations Centre for Human Settlements (Habitat) 2001; United Nations Human Settlements Programme 2007), 136 countries (79 %) had faster increases in household numbers than population sizes during 1985–2000 (Fig. 6.1). Over the period of 2000–2030, an even higher percentage of countries (91 %) are projected to have faster growth in household numbers than population sizes (Fig. 6.1).

At the global level, household intensity (number of households per 100 persons) increased 12.6 % from 1985 to 2000. At the country level in 1985, the average household intensity was 22.9 households per 100 persons, and Jordan had the lowest intensity (7.9) while Sweden had the highest density (43.9, Fig. 6.2a). By 2000, the average household intensity increased to 25.8 households per 100 persons. The lowest and highest intensities also increased. Sweden still held the highest spot (48.1), but the country with the lowest intensity had switched to Liberia (9.7) (Fig. 6.2b). The trends of increases in household intensity are projected to continue into the future (Fig. 6.2c).

Over time, a country can have fewer people but more households. During 1985–2000, population declined in 12 countries, but their household numbers increased

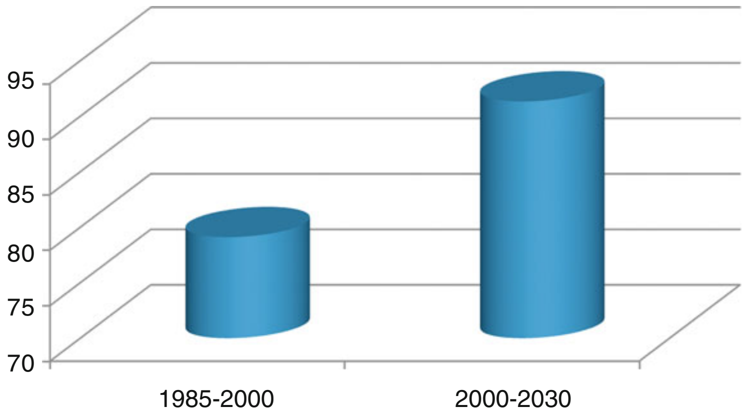

Fig. 6.1 Percentages of countries with faster growth in household numbers than population sizes (actual: 1985–2000, and projected: 2000–2030)

(Fig. 6.3a). For example, Ukraine had a reduction of 1.8 million people but an increase of 1.3 million households. Over the period of 2000–2030, it is projected that 20 countries will experience lower population sizes but higher household numbers (Fig. 6.3b). Russia is projected to have the largest population decline (approximately 21.2 million) but an increase of more than 10.3 million households.

The differences in rates of growth in household numbers and population sizes were due to reductions in household sizes (number of people per household), as a result of such factors as increased nu divorces and declined multigeneration families (Liu et al. 2003). If the average household size in 2000 (3.9 people per household) had remained at the 1985 level (4.4 people per household), there would have been 172 million fewer households in all countries combined by 2000. In other words, there were 172 million "extra" households due to the decline in the average household size alone. It is projected that household sizes will continue to reduce during the period of 2000–2030 and there will be 756 million additional households by 2030 due to reduction in household size alone (with an average household size of 3.1 people per household).

While the discussion above focused on household proliferation at the global and country levels, household proliferation is also common at the regional and local levels. For example, in Wolong Nature Reserve of southwestern China for the conservation of giant pandas, human population size rose from 2,560 in 1975 to 4,550 in 2005, while the number of households jumped from 421 to 1,156 during the same period. In other words, the increase in the number of households was more than twice (174.6 % increase) the increase in the number of people (77.7 % increase). In many regions such as New Zealand (Liu et al. 2003), the numbers of people declined, but the numbers of households continued to increase because household sizes decreased (Liu et al. 2003).

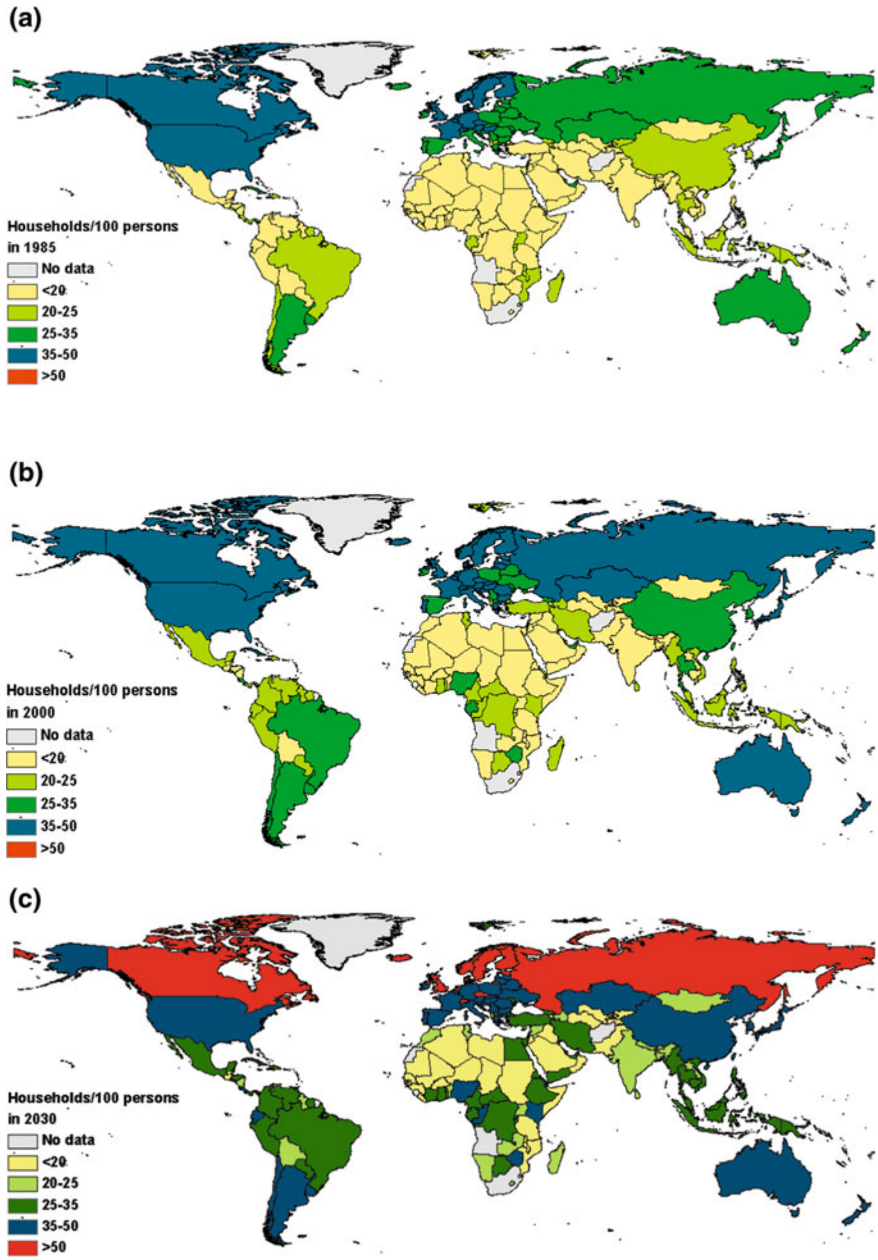

Fig. 6.2 Household intensity in **a** 1985, **b** 2000, and **c** 2030 (projection)

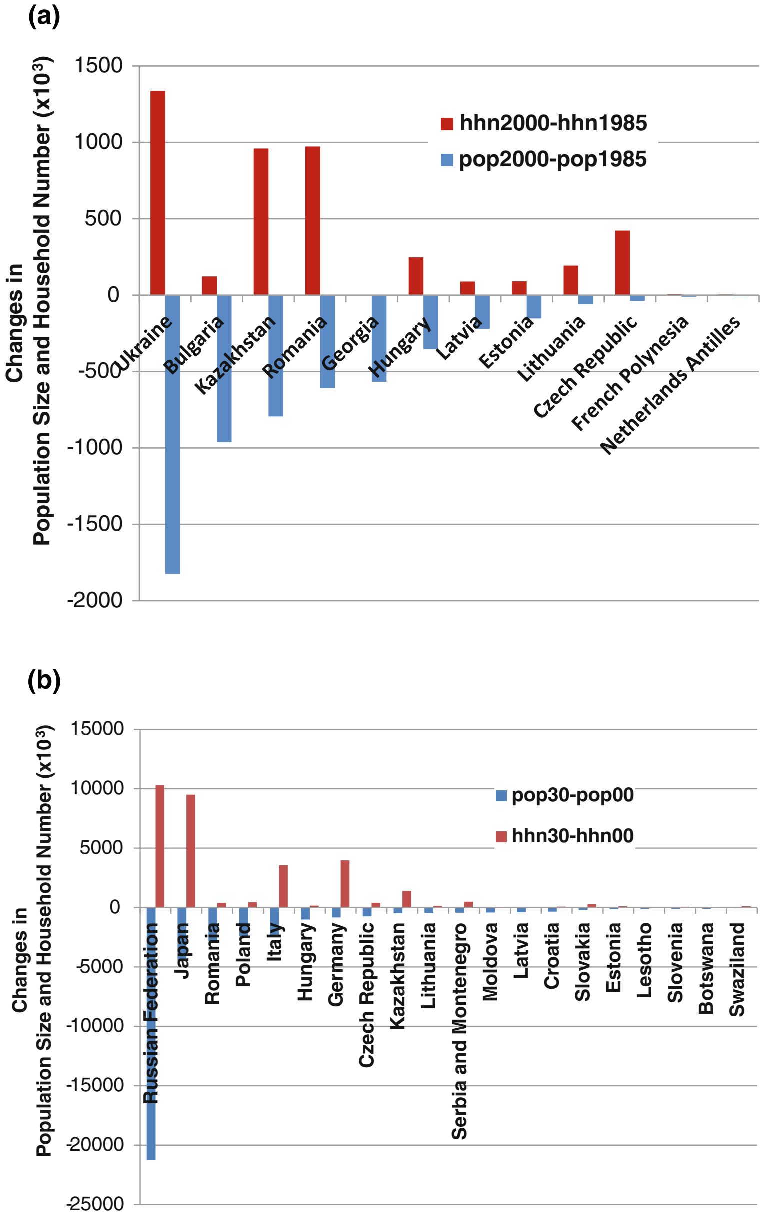

Fig. 6.3 Countries with declined population sizes but increased household numbers during **a** 1985–2000, and **b** 2000–2030 (projection). "pop00–pop85" (and "hhn00–hhn85") indicate the differences between population sizes (numbers of households) in 2000 and 1985. Similarly, "pop30–pop00" (and "hhn30–hhn00") are the projected differences between population sizes (and numbers of households) in 2030 and 2000

6.3 Effects of Household Proliferation on Ecosystem Services

The effects of household proliferation on ecosystem services (provisioning, supporting, regulating, and cultural services) may differ from those of population growth because patterns of household proliferation and population growth vary (Table 6.1).

6.3.1 Demand and Supply of Ecosystem Services

As the number of households increases, so does demand for ecosystem services (or consumption of ecosystem services). This is because more households need more ecosystem services and the efficiency of using ecosystem services is lower per capita in smaller households. For example, more households demand more timber

Table 6.1 Actual and hypothetical impacts of household proliferation on ecosystem services

Type of ecosystem service	Impact of household proliferation (examples)
Provisioning services	
Food (e.g., grains, seafood, spices)	Reduces area for food production (e.g., cropland and other areas suitable for wild foods and spices) through land conversion to residential area (Fazal 2000; Matuschke 2009)
Fresh water	Pollutes water through release of household waste and changes hydrological cycles through land-use change (e.g., application of chemical fertilizers and pesticides for lawn maintenance) (Office for Official Publications of the European Communities 2001; Robbins et al. 2001; Adedeji and Ako 2009; Natural Way 2011)
Fuel, wood, and fiber	Reduces area for production of fuel, wood, and fiber (e.g., fuelwood) through land conversion to residential area (FAO 2002; Carrero and Fearnside 2011)
Pharmaceuticals (e.g., herbal plants, and wildlife)	Destroys plants directly and indirectly (through changes to habitat) (An et al. 2006)
Regulating services	
Carbon sequestration, and climate regulation	Emits CO_2 (Dietz et al. 2009); plants trees and protects forests that sequester CO_2 (Liu et al. 2007)
Flood regulation	Reduces areas (e.g., wetlands) for flood regulation because of land conversion (Schuyt 2005)
Waste decomposition and detoxification	Destroys organisms and habitat of organisms that can decompose waste and toxins (Alavanja 2009)
Purification of water and air	Harms organisms that can purify water and air (Sládeček 1983); creates habitat for biodiversity (e.g., plants, wildlife) that can purify water and air (Liu et al. 2007)

(continued)

Table 6.1 (continued)

Type of ecosystem service	Impact of household proliferation (examples)
Crop pollination	Reduces habitat for pollinators (Hansen et al. 2005); raises honey bees that can enhance pollination (Ogaba 2002)
Pest and disease control	Reduces habitat for natural enemies, spreads pests and diseases (e.g., by introducing garden plants) (Schöller et al. 1997), and creates habitat for pests and diseases; creates habitat for natural enemies and destroys habitats for pests and diseases (Altieri 1993)
Supporting services	
Nutrient cycling	Disrupts nutrient cycling through land conversion (to houses and infrastructure such as roads and other buildings) and creation of barriers (Kaye et al. 2006)
Soil	Uses soil as household construction material, and affects chemical and physical properties of soils through construction of associated infrastructure (e.g., roads, buildings) (Graf 1975)
Seed dispersal	Prevents seed dispersal by forming impermeable surfaces (e.g., houses, roads) (Coffin 2007); facilitates seed dispersal through travel and shipping (Lodge et al. 2006)
Primary production	Damages and occupies areas for primary production through land conversion (Liu et al. 2001)
Cultural services	
Cultural, aesthetic, intellectual and spiritual inspiration	Destroys areas and remnants of cultural and spiritual significance through construction of housing and associated infrastructure (Marsh 1992)
Recreational experiences (including ecotourism)	Destroys through construction and occupies areas suitable for ecotourism (Anderson and Potts 1987)

The impacts of household proliferation are different from those of population growth because patterns of household proliferation and population growth are not the same. For the sake of simplicity, the impacts are phrased in a linear manner, but the actual relationships are much more complex and are often nonlinear with thresholds

for house construction and furniture (Liu et al. 2005), and more fuelwood for heating and cooking. As to fuelwood consumption, a decrease in household size increases fuelwood consumption per capita (An et al. 2001) (Fig. 6.4). This is because houses with different numbers of people used similar amounts of fuelwood for heating. In terms of cooking, more fuelwood is consumed in a large household because more food needs to be cooked for more people, but the efficiency per capita is still higher in a larger household if other conditions are similar (Liu et al. 2005).

On the other hand, households can be ecosystem service producers. For example, some households raise honey bees that are major pollinators (Ogaba 2002), while some other households cultivate plants and flowers in their yards to feed pollinators that can help enhance food production. Some households create habitat for wildlife species and enhance biodiversity, which can generate a variety

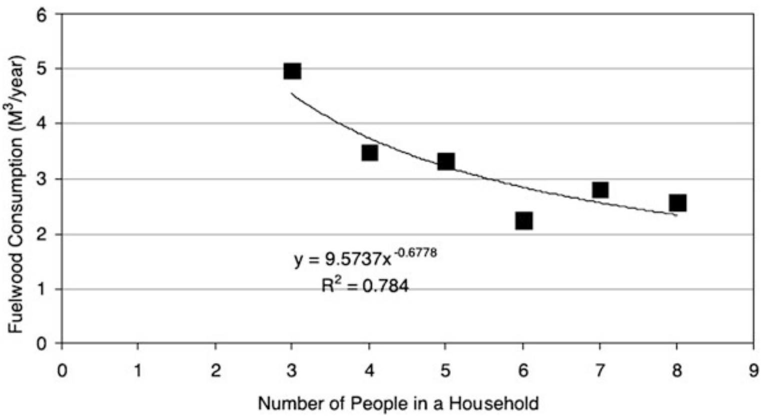

Fig. 6.4 Fuelwood consumption per capita under different household sizes (Liu et al. 2005)

of ecosystem services. Some households also plant trees and protect forests that sequester CO_2, such as those who reduce greenhouse emissions from deforestation and forest degradation (REDD) (The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries 2012), and who monitor forests from illegal harvesting, such as in China's National Forest Conservation Program (Liu et al. 2008). However, the supply of ecosystem services from households is much less than the demand for ecosystem services. As a result, ecosystem services continue to degrade rapidly (MA 2005).

6.3.2 Impacts on Ecosystem Services

Household impacts on ecosystem services are enormous (Table 6.1). In this section, two examples are given to illustrate the impacts.

6.3.2.1 Impacts of Household Proliferation on Forests and Panda Habitat

Household proliferation is an important contributor to the significant changes in forests and panda habitat in Wolong Nature Reserve. From 1965 to 1997, forest cover and suitable panda habitat in Wolong was substantially reduced (Liu et al. 2001) (Fig. 6.5) because people had used ecosystem services (e.g., fuelwood and timber) in areas that pandas use. Both people and pandas prefer areas that are not too steep. The suitable panda habitat has been much fragmented by human activities (e.g., fuelwood collection, timber harvesting, road construction, and home building). With increases in the total amount of fuelwood consumption and

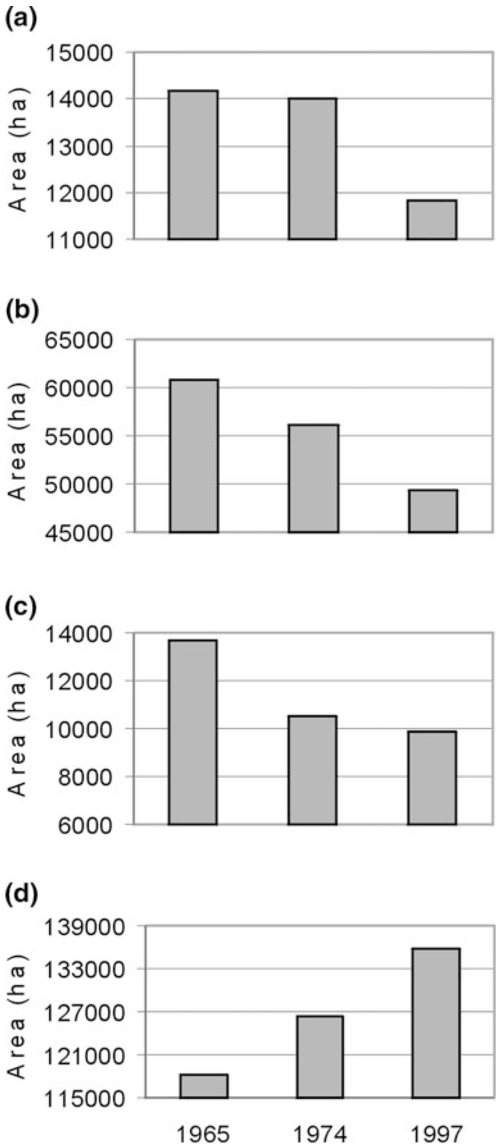

Fig. 6.5 Change in the amount of panda habitat in Wolong Nature Reserve before and after the reserve was established in March 1975. **a** Highly suitable habitat, **b** suitable habitat, **c** marginally suitable habitat, and **d** unsuitable habitat (Liu et al. 2001)

exhaustion of forests near households, local residents went to areas far away from their homes to collect more fuelwood. Consequently, the average distance between homes and locations of fuelwood collection increased over time (He et al. 2009). Fuelwood collection in those remote areas is more damaging to pandas because they are the most suitable panda habitat (Fig. 6.6).

The quantity of panda habitat is more sensitive to factors related to household numbers than to population sizes (An and Liu 2010). Simulations using an agent-

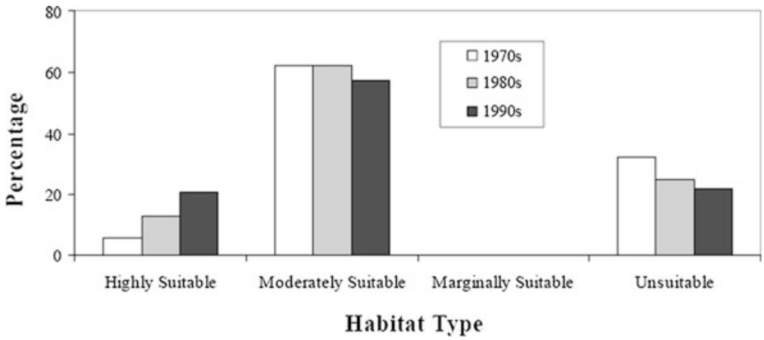

Fig. 6.6 Percentages of fuelwood collection sites in three decades (1970s, 1980s, and 1990s) falling in four types of habitat (He et al. 2009)

based model indicated that household numbers varied very differently than population sizes (An and Liu 2010). Fertility-related factors (e.g., fertility rate, spacing between births, and upper child-bearing age) caused almost instant changes in population size. All the factors except age at the first marriage had time lags of approximately 20 years before they affected household numbers. Age at the first marriage changed household numbers most quickly. A reduction of age at the first marriage from 38 to 18 could lead to a difference of 90 households at year 5, 150 households at year 10, and approximately 220 households at year 20. This is largely because of the household lifecycle: delayed marriage usually postpones the formation of new households and births of babies. It takes more time for other factors to take effect in changing household numbers. For example, increasing fertility rate increases the number of children, but the children still stay with their parents until they establish their own households. This is why there is a time lag of approximately 20 years.

Changing household numbers through age at the first marriage is the most effective and fastest way to lower panda habitat loss. Panda habitat is more influenced by household numbers than population size. This is partly due to how fuelwood is consumed. A major proportion of fuelwood is used for heating, which changes little when an existing household has one more or one fewer person. In terms of cooking, adding or removing one person does not change fuelwood use much (An et al. 2001).

6.3.2.2 Impacts of Household Proliferation on Food Production

Household proliferation also has substantial impacts on other ecosystem services, such as food production (Table 6.1). Because household proliferation requires more areas for housing and associated infrastructures (e.g., roads and sewer services), much agricultural land has been converted into residential areas around the world. Although there are no accurate statistics at the global level, there are numerous reports at the local level. Here are three examples from Africa, Asia, and South America. In Accra (Ghana, Africa), 2,600 ha of agricultural land per year were converted into residential areas (Maxwell 2000). From 1995 to 2005, Ho Chi Minh City of Vietnam lost more than 10,000-ha agricultural land to housing, roads, and other built-up areas (Van 2008). Similar patterns are common in China and Indonesia (Verburg et al. 1999; Weng 2002). In the Pampas ecoregion of Argentina, 39,187 ha of farm land have been converted to exurban use (Matteucci and Morello 2009). An immediate impact of housing expansion is the loss of peri-urban agriculture, which is usually significant in providing perishable food to the urban areas (Matuschke 2009). As a result, agricultural production may be forced to shift to less productive areas and result in yield losses and increased cost of transport.

Food production is further compromised by the use of water by more households because more households require more water for daily consumption and reduce the retention of water because of the impervious surfaces. After the surface water and groundwater in the residential areas cannot meet household demand for water, households have drawn water from far places. This creates cascading effects on distant ecosystem services (Liu et al. in press) and reduces the capacity of food production in distant places (by lowering water table and increasing dry zones in soils), in addition to the agricultural areas that have been converted for residential use. All these affect food security and water security, and ultimately security of all ecosystem services.

Historical trends in household size suggest that there will be many more households even if human population declines. If average household size worldwide were the same as that of the United States (2.5 people per household) in 2010, then the world would have over 40 % more households, or 800 million additional households in the 172 countries with available data (2.7 billion households rather than 1.9 billion households). If each household occupied a 210 m^2 house (the average U.S. house size in 2002), then 168,000 km^2 extra housing area would be required. Even assuming each house has two-stories, then housing needs 89,000 km^2 of additional land area. That would be twice the size of California. Even if the average house globally is half of an average U.S. house, 44,500 km^2 would be needed to accommodate additional households. These estimates have not taken land area for other purposes associated with housing (e.g., infrastructure such as roads, services, yards) into account. Including land for associated functions would require 2–4 times as much land for each home. So the total area for housing would take up nearly half the size of the continental United States (Peterson et al. in press) and severely limit food production.

6.3.3 Payments for Ecosystem Services

Household proliferation has important effects on payments for ecosystem services because many payments for ecosystem services programs are implemented at the household level. For example, China's grassland ecocompensation program distributes 500 yuan (US $1 = 6.35 yuan as of July 2012) to each household regardless of household size (General Office of the State Council of the People's Republic of China 2010). As there are 2 million households, the total amount of funding needed for all the households is one billion yuan. Thus, the more households, the higher the total amount of payment is needed when the amount of payment for each household is fixed. On the other hand, if the total amount of funding in the program is fixed, each household would receive a smaller amount when there are more households.

More households also can generate a higher amount of funds if they are willing to pay for ecosystem services. For example, Loomis et al. (2000) found that a sampled household would be willing to pay an average of $252 annually (through a higher water bill) to restore five ecosystem services (dilution of wastewater, natural purification of water, erosion control, recreation, and habitat for fish and wildlife) along a 72 km section of the Platte River in the State of Colorado, USA. Extrapolating the result of the sampled 96 households to all households (281,531) living along the river may reach $71 million. However, if a quarter of the households are willing to pay, only $18 million can be collected.

6.4 Research Directions and Management of Ecosystem Services

Household proliferation has been rarely considered in ecosystem services research and management (e.g., valuation) although it may play key roles in ecosystem services and sustainability (Table 6.1). As illustrated above, household dynamics are different from population dynamics because household numbers can increase even though population sizes are stable or even decline. Many questions must be addressed, for example, How do we meet household demands for ecosystem services? How do we reduce household impacts on ecosystem services? How do we determine the most appropriate amounts of payments for ecosystem services in the context of household proliferation? How do households enhance ecosystem services and improve efficiency in using ecosystem services?

New research directions are needed to address questions such as those raised above and test hypotheses such as those listed in Table 6.1. The solutions may include (1) changes in the conceptual frameworks of valuing ecosystem services from static to dynamic processes by incorporating household demand and impacts, (2) changes in research approaches from population-focused to households-focused, and (3) changes from discourse within the ecological and economic communities in valuing ecosystem services to collaborating with researchers in other disciplines (e.g., demography). By collaborating with action-oriented stakeholders and households, the ecological community will be in a stronger position to turn discoveries into actionable knowledge for sustainability of ecosystem services.

The effects of household proliferation may be complex (e.g., with nonlinear relationships and thresholds). Addressing these complexities requires new data and novel tools. Data on household proliferation are not as readily available as population sizes because population sizes are more frequently sampled and widely reported. Obtaining relevant household data is more time-consuming, more complicated, and more costly than research using data on population dynamics.

It is encouraging, however, that new opportunities to address household proliferation are also emerging. More advanced tools for collecting, analyzing, and visualizing data are becoming available. For example, high-resolution remotely sensed data such as QuickBird and IKONOS can help identify locations of housing units (An et al. 2005). A combination of on-the-ground interviews, documents from relevant institutions such as government agencies, and remote sensing data will be helpful in understanding impacts of household proliferation on ecosystem services. Dynamic and interactive web sites (e.g., blogs, social media) and citizen science may provide new tools to understand household demand for ecosystem services.

Current monitoring programs on ecosystem services include indicators of ecosystem services themselves (Table 6.1). To more accurately predict changes in ecosystem services and take proactive adaptive management measures, it is crucial to monitor indicators that affect changes in ecosystem services directly and indirectly, including factors that shape household dynamics. Thus, monitoring efforts should be expanded, especially in areas with severe degradation of ecosystem services, to indicators in human dimensions (e.g., values and attitudes toward household formation and ecosystem services).

Household proliferation generates more complications for ecosystem service management and policy than population growth. In fact, some payments for ecosystem services programs stimulate the formation of new households because the payments are implemented at the household level and dividing a household into two can double the payments (Liu et al. 2007). To achieve sustainability of ecosystem services, current management and stewardship approaches need to adopt a new structure to fully integrate household proliferation and strive to enhance positive and reduce negative effects of household proliferation.

6.5 Conclusions

Global household proliferation provides both challenges and opportunities for research and governance of ecosystem services in coupled human and natural systems across local to global levels. It is projected that household proliferation will intensify even faster than population growth globally in the future. As household proliferation has important implications for demand and impacts on ecosystem services, it should be incorporated into ecosystem services research, monitoring, and scenario analysis. Incorporating household dynamics into research across landscapes around the world would lead to unique new insights. Such research also would generate useful information for managing and governing ecosystem services at a time when the ecological community is faced with unprecedented obligations to address societal needs such as achieving ecological sustainability while improving human well-being worldwide.

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