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Source: Tropical Conservation Science, 1(4) : 307-320

Published By: SAGE Publishing

URL: https://doi.org/10.1177/194008290800100402

Conservation Letter

Integrating landscapes that have experienced rural depopulation and ecological homogenization into tropical conservation planning

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Abstract

If current trends of declining fertility rates and increasing abandonment of rural land as a result of urbanization continue, this will signal a globally significant transformation with important consequences for policy makers interested in conservation planning. This transformation is presently evident in a number of countries and projections suggest it may occur in the future in many developing countries. We use rates of population growth and urbanization to project population trends in rural areas for 25 example countries. Our projections indicate a general decline in population density that has either occurred already (e.g., Mexico) or may occur in the future if current trends continue (e.g., Uganda). Using both temperate and tropical examples we present evidence that this process will lead to ecological homogenization as a dominant habitat (e.g., forest replaces a mosaic of human-maintained landscapes), resulting in declines in biodiversity at the local scale. Building on this information, we consider research programs that need to be conducted so that policy makers are prepared to effectively manage depopulated rural areas.

Keywords: population growth rates, restoration, rural depopulation, social desertification, urbanization

Resumen

Si la caída de los índices de fertilidad y el abandono de las zonas rurales como resultado de un proceso de urbanización general continúan, resultarán en una transformación significativa a nivel global con consecuencias importantes para los diseñadores de políticas públicas interesados en protección medioambiental. Esta transformación se está haciendo evidente en un creciente número de países y las predicciones sugieren que en el futuro puedan ocurrir en muchos países en vías de desarrollo. Utilizamos niveles de crecimiento demográfico y urbano para proyectar las tendencias demográficas en zonas rurales para 25 países. Nuestras proyecciones indican un declive general en la densidad de la población que ya ha ocurrido (México) o que ocurrirá en un futuro no muy lejano (Uganda). Utilizando ejemplos de zonas temperadas y tropicales a la vez, presentamos evidencias que demuestran que este proceso llevará a una homogenización ecológica debido a que un tipo de hábitat dominante (como el bosque) tiende a reemplazar el mosaico de paisajes mantenidos gracias a la actividad humana, resultando en reducciones de la biodiversidad en una escala local. Esta información nos permite afirmar que se deben desarrollar programas de investigación que preparen a los diseñadores y gestores de políticas de conservación para el manejo efectivo de zonas rurales en proceso de despoblación.

Palabras clave: crecimiento de la población, restauración, despoblamiento rural, desertificación social, Received: 12 August, 2008; Accepted 27 October, 2008, Published: 1 December, 2008

Cite this paper as: Jacob, A. L., Vaccaro, I., Sengupta, R., Hartter, J. and Chapman, C. A. 2008. Integrating landscapes that have experienced rural depopulation and ecological homogenization into tropical conservation planning. *Tropical Conservation Science* Vol.1 (4):307-320. Available online: www.tropicalconservationscience.org

Introduction

A major challenge in tropical land management is to meet the demands for agricultural lands, while conserving biodiversity and providing critical ecosystem services [1]. However, there is evidence that in some countries the nature of this challenge may change in the near future. The acceleration of two demographic trends, increasing urbanization and decreasing fertility rates, has the potential to significantly change the conservation challenges in the future if current trends continue [2, 3]. First, current patterns are being eroded in favor of growing urbanization. In 1950, 29% of the world's population lived in urban settings; by 2030 this figure is projected to be 60% [4]. The majority of growth is projected to be in urban centers of developing countries, while rural areas will become increasingly depopulated [5, 6]. Second, the fertility rates of many societies are declining and are projected to progressively slow the global population growth rate until it stabilizes at the end of the 21st century [7, 8]. In some countries, shifts from agrarian to industrial economies and declining fertility rates have already led to widespread abandonment of pasture and agricultural lands and increasing rates of natural reforestation [2, 5, 9-12]. Land management policies will need to change where these two demographic trends co-occur, and to change, land managers must have appropriate supporting information.

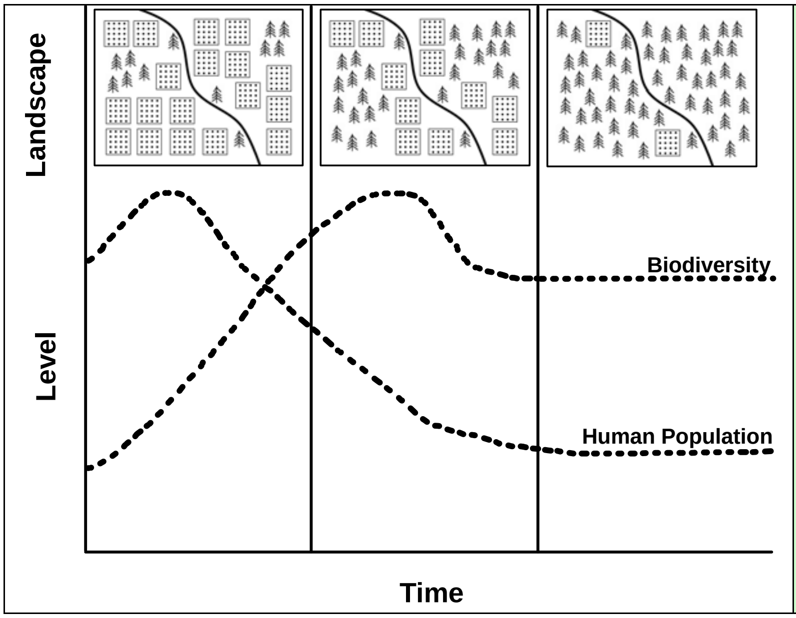

Fig.1. The hypothetical relationship between rural depopulation and biodiversity and three inlays illustrating the nature of the landscape at different stages of ecological homogenization in the process of rural depopulation.

In situations where rural depopulation is occurring, there are two primary reasons why policy must change. First, with depopulation of rural areas there should be opportunities for mutually beneficial land-use conservation agreements between policy makers and the few remaining farmers or ranchers, to extend conservation lands or to meet conservation goals in landscapes with infrequent human use. Second, this combination of demographic and social trends creates a novel ecological situation (Fig. 1). Landscapes with a mosaic of habitats and high levels of local biodiversity (i.e., both habitat and species richness) previously maintained by anthropogenic activities are gradually replaced by a regenerating habitat type (e.g., forest). This process of ecological homogenization results in a net loss of biodiversity at the local scale as it causes the disappearance of multiple habitats sustaining a wide variety of fauna and flora that cannot adapt to the dominant habitat. By homogenization, we refer to the simplification of the ecological mosaic at the local scale through consolidation of dominant habitat type in a landscape mosaic previously characterized by anthropogenic activities and fragmentation. The time scale considered will be critical for evaluating the effect of land abandonment. Initially, biodiversity is likely to rise as there will be a mosaic of habitats and young successional forest that can support a diversity of species [13]. It will only be when the successional forest is progressively replaced by stands of mature forest that one will see the full effect of ecological homogenization on reducing biodiversity. The time scale over which this will occur will be very dependent on the nature of the disturbance and the system involved [14, 15]. Also, it should be stressed that from a biodiversity conservation perspective, homogenization need not be a negative outcome. For example, species requiring large ranges will likely benefit. Conservation managers need to consider which outcome is most desirable for the species of interest and the situation in question.

In this article we illustrate how the combination of declining population growth rates and increasing urbanization leads to depopulated rural landscapes, and consequently to environmental recovery and ecological homogenization. First, we graphically contrast demographic trends in 26 countries, both tropical and temperate, to illustrate that rural depopulation is a general trend, but that different countries are at different phases of this process. Next, we present a detailed description of regions of Spain and Mexico that are well along in this process of rural depopulation. Next, we use the example of Kibale National Park in Uganda to illustrate how this homogenization process occurs in protected areas when previously heterogeneous environments receive severe restrictions on human uses. This serves as both a proxy of areas experiencing rural depopulation and is also an important issue to maintain habitat diversity in some protected areas. Finally, we consider the policy implications of this process, and propose research programs that conservation biologists and researchers in related fields might want to initiate if we are to provide policy makers with the information necessary to appropriately change policy. Our goal is to initiate a dialog within the scientific community about how best to deal with this future scenario. In many cases, policy managers do not have the protection of regenerating landscapes as part of their mandate, and since it can take decades for conservation policies to change and be effectively implemented [16-18], our forecasting exercise may be useful in shaping research hoping to provide civil society with information needed to plan for possible futures. We fully realize that the scenario where depopulated rural areas are left to recover is only one of a number of possible futures for depopulated lands, with other futures including industrial agriculture. However, we present evidence that this is occurring over large areas, thus we view that it is worthwhile to consider this possibility in detail.

Methods

We used three approaches to evaluate rural depopulation caused by urbanization and reduced fertility rates. (1) First, we examined global patterns in rural depopulation by randomly selecting six countries from each of three development categories used by the United Nations: More Developed Regions, Less Developed Regions, and Least Developed Countries, and six countries of special interest that are either of particular global economic importance or where one or more of the authors have specific knowledge of depopulation and ecological homogenization trends (Fig. 2, 3). We used the World Urbanization Prospects: The 2007 Revision Population Database (http://esa.un.org/unup/index.asp?panel=2) [19] to obtain the rural annual growth rate and the annual rate of change of the rural population for each of these 24 selected countries, expressed in five-year intervals starting in 1950 and projected to 2050 [19]. Since the rural annual growth rate includes both births and in-migration of rural people, the annual rate of change of the rural population (%) was used to approximate the rate of people moving from rural to urban areas (urbanization). We graphed these rates against time and calculated linear regression equations from the earliest five-year interval where the graphed line showed a consistent linear pattern in rural density, i.e., where the line was more or less stable. We graphically present these results in two ways. First, starting with a hypothetical initial rural density of 100 people/km^2 in 1950, we applied the linear regressions in an iterative manner until the year 2200. We used the same hypothetical initial rural density for each country, rather than actual country-by-country data, to illustrate the process of rural depopulation in different nations. This approach is not intended to make specific predictions about population densities in the future, but rather it illustrates a process. This has the advantage of illustrating the process, but the disadvantage of not portraying how actual rural populations will change. To circumvent this limitation we project actual population change for the six countries of special interest. Using this approach has the fallback that the size of urban centers is not presented in the databases that we use and thus we are forced to assume that urban centers represent a small and unchanging proportion of the total countries area. However, by presenting both approaches the reader can both clearly evaluate the process and see how actual density will vary over time. (2) Second, since one or more of the authors have long-term research projects in Mexico, Spain, or Uganda, we drew on each author's experience concerning trends of depopulation and the ecological consequences in these countries. (3) Third, we examined the literature dealing with land cover and biodiversity change in situations of diminishing human pressure.

Results and Discussion

Our analysis illustrates that there is a general process whereby the combination of declining population growth rates and urbanization leads to decreasing rural population density (Fig. 2). The countries illustrated here are aggregated by development status as defined by the United Nations [19]. Different countries are at different stages of this demographic process and will thus experience changes in rural depopulation at dissimilar times. With respect to the three countries on which we focus, Spain is the farthest along a path of rural depopulation, Mexico is in the middle, and Uganda has not yet started this process; however these three countries provide useful examples to consider the consequences of rural depopulation and ecological homogenization. For Spain the annual rate of growth for rural areas between 1950 and 1955 was negative, while Mexico's and Uganda's growth rates were both positive, but Mexico's was less than Uganda. Between 2045 and 2050, the annual rural growth rate is projected to be strongly negative for both Spain and Mexico, and weakly positive for Uganda. In 1950, 3% of Uganda's population lived in urban areas, while in Mexico and Spain this figure was 43%, and 52% respectively. In contrast, in 2030 the percentage of the population living in urban areas is expected to grow to 82% by in Spain, 83% in Mexico and only 21% in Uganda. Using the countries' actual density in 1950 does not alter the basic pattern of change, but illustrates strong differences in the initial population densities of the six countries of interest (Fig. 3).

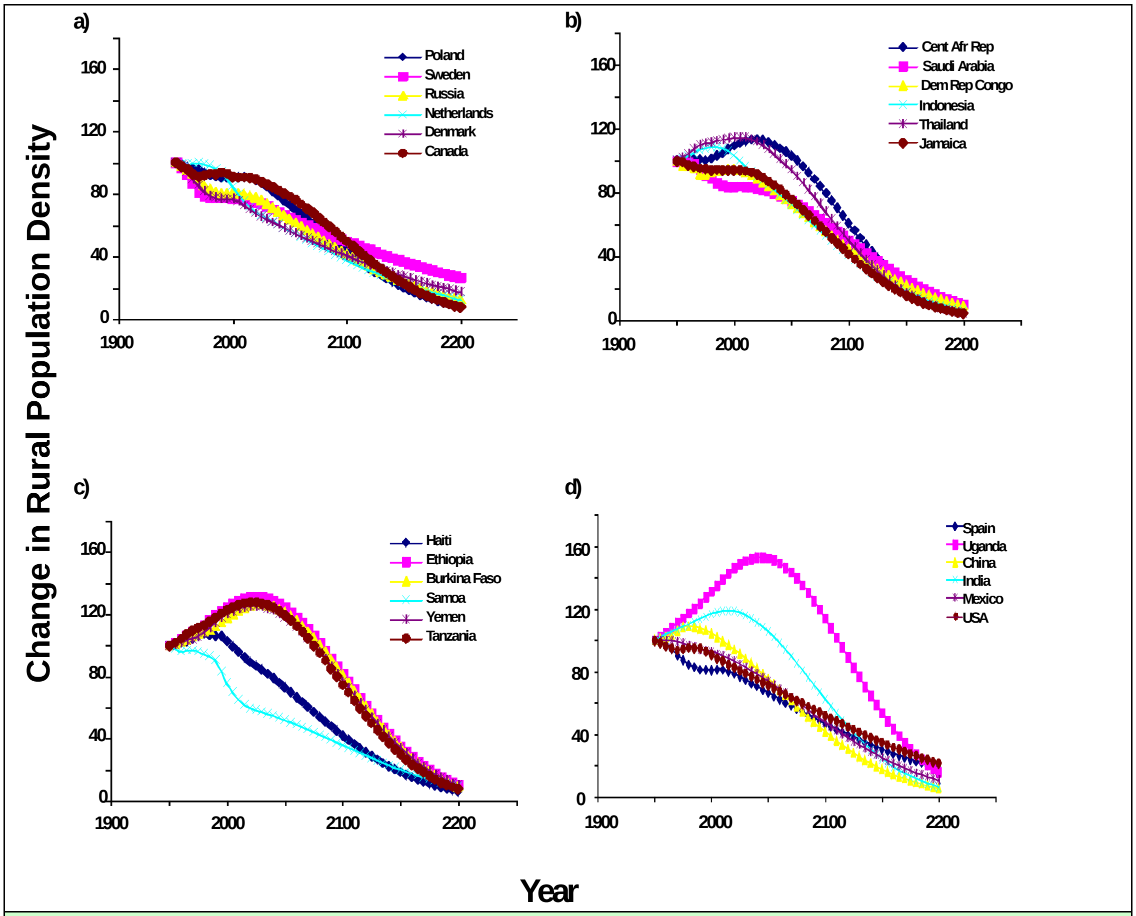

Fig. 2. Projected rural population growth rates for 25 countries from an initial assigned density of 100 people / km^2. Countries were aggregated into three development categories as defined by the United Nations [19]: a) more developed regions, b) less developed regions, and c) least developed countries. Six countries were randomly selected from each of these three categories, excluding those with population < 100,000 in 2007. d) Additionally, six example countries were non-randomly selected because they are dealt with in detail in our research (Uganda, Mexico, Spain), or are of interest because of their influence on the global environment (India, China, USA). For graphical comparisons, each country is assumed to have an initial rural population size of 100 people/km^2. The definition of what constitutes an urban or rural area differs according to the criteria used by each country (United Nations, 2008). Any person not inhabiting an area classified as urban is counted in the rural population.

The experience of rural depopulation and subsequent environmental change in Spain offers insights into the futures of other countries. During the last 70 years, the Pyrenees mountain range of Spain has experienced high rates of depopulation, so severe that at times this phenomenon was referred to as "social desertification" [20-22]. While Spain has an overall density of 79 people/km^2, the Pyrenean districts of Aragon have an average density of 6 people/km^2 [23]. Similarly, the Pallars Sobirà District experienced a reduction in population from 12,972 inhabitants in 1900 to 5,049 in 1991. There has also been an altitudinal relocation of the population from mountainous areas to valley bottoms [24]. For example, there has been a fundamental change in the percentage of population living in towns and villages in this district under 1000 m from 36% in 1900 to 60% in 1991 [25]; Fig. 4). These demographic changes have lead to environmental change, as it is the disappearance of human pressure that allows forest expansion [21, 26]. Roura-Pascual et al. [27] quantified increases in forest cover in municipalities of the French Catalan Pyrenees from 32% of the area in 1953, to 52% in 2000. Landscape depopulation and subsequent environmental transformation led to changes in the region's conservation status, and conservation policies are now an important part of the landscape (in 2004 the six districts of the Catalan High Pyrenees had 38.5% of their territory under some form protection). The predominance of conservation policies is not disconnected from depopulation and reforestation [25, 26]. The location of protected areas is highly correlated with abandoned or seasonally used land and new protected areas reinforce the reforestation trends.

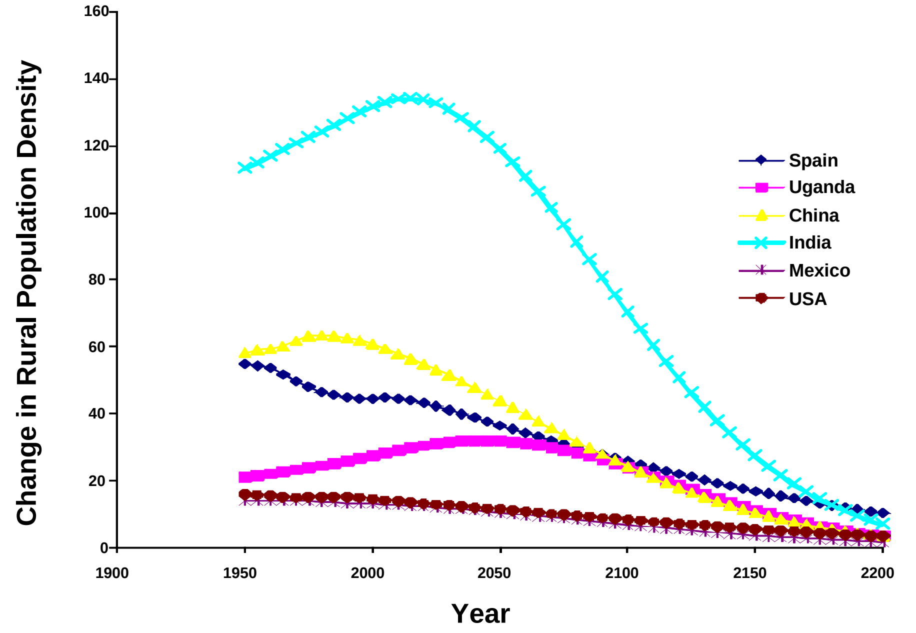

Fig. 3. Change in rural population density from six non-randomly selected countries. These countries were selected because one of the authors has research projects in them (Uganda, Mexico, Spain), or are of interest because of their influence on the global environment (India, China, USA).

Similar regrowth in forest areas was quantified by a land use-land cover change analysis performed for the Rio Cuale watershed in the state of Jalisco, Mexico. Landsat imagery from 1979, 1990, and 2002 was used to detect changes within the watershed landscape [28]. This analysis revealed that forest cover within the watershed increased during this period by 640 ha. The annual rate of forest recovery was 38 ha/year for the 1979-1990 period and 14 ha/year between 1990 and 2002 (Fig. 4). Interviews and analysis of demographic data of the residents revealed that the lack of high schools and job opportunities in the rural areas encouraged migration of the youth to the nearby city of Puerto Vallarta; a tourist center with greater economic opportunities [29]. Migrants either return to the rural localities during the farming season to help their families, or remain in the urban center, losing interest in their rural livelihoods. Further, with agricultural intensification occurring in other parts of Mexico combined with the fact that corn yields in the Rio Cuale watershed are low, there is a disincentive for farmers in the watershed to expand their agricultural activities. This mirrors the trend of land abandonment elsewhere in Mexico, particularly in predominant regions of rain-fed agriculture performed in marginal lands [30].

Ecological homogenization, such as that described for Mexico and Spain, is not happening in the Ugandan countryside and Uganda is still mostly an agrarian population with heavily populated rural areas (96 individuals/km^2 average nationwide, but over 250 individuals/km^2 in some areas) [31, 32]; it is experiencing continual forest loss. Tropical forest once covered 20% of the country (39,942 km^2), but deforestation has reduced this to just 3% (5,991 km^2) [33]. Furthermore, Uganda lost 18% of its remaining forest between 1990 and 2000 [33]. The most recent estimate suggests that the annual rate of loss of tropical forest is 7% although this rate is slowing down [34].

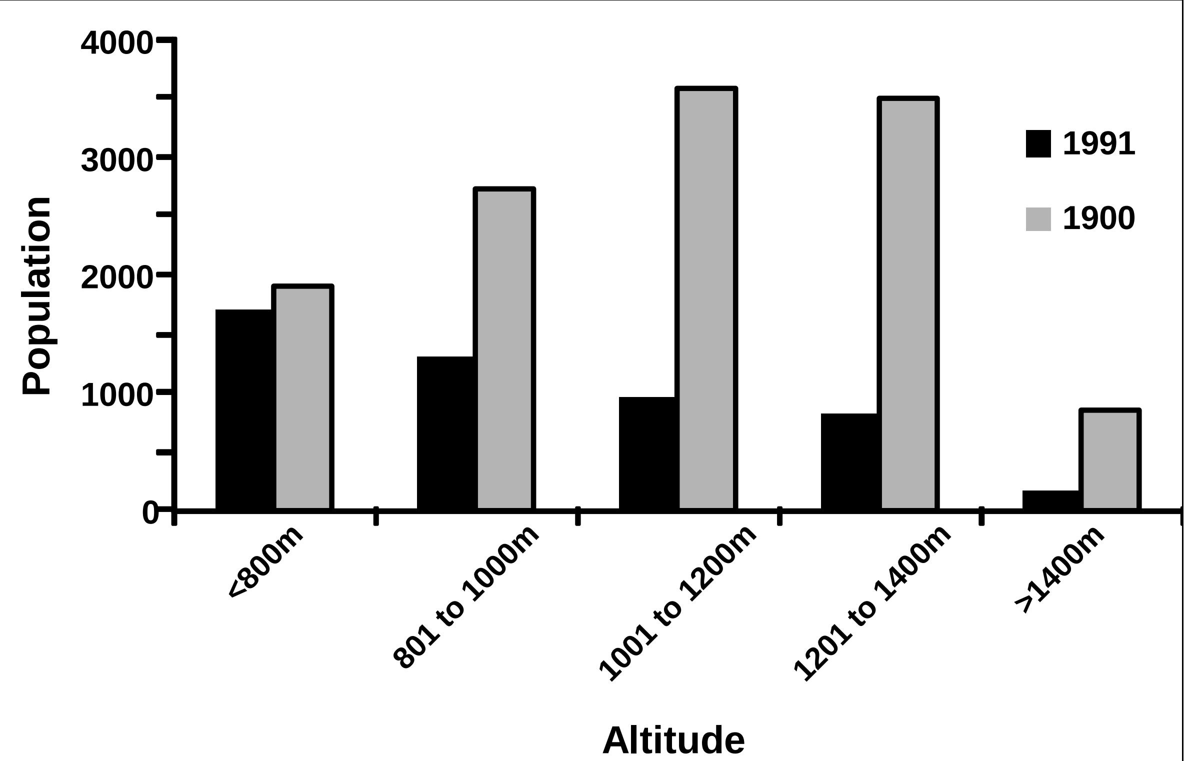

Fig. 4. Changes in population size in the Pallars Sobira region of Spain between 1900 and 1991 as a function of elevation.

Although ecological homogenization is not yet happening in Uganda as a whole (Fig. 2, 3), this process is occurring in situations where human pressures on the environment have been removed. As with depopulated rural areas, protecting areas with a diverse matrix of habitat previously maintained by anthropogenic disturbances will result in habitat homogenization once the area is extracted from human modification. Kibale National Park, Uganda, provides an excellent example of this process. Kibale was gazetted a Crown Forest Reserve in 1932 when rinderpest devastated livestock and agricultural areas were abandoned. As a Forest Reserve, protection was limited and grasslands were maintained by fires primarily set by hunters. However, in 1993 the reserve was gazetted a national park and as a result human pressures inside the park were dramatically curtailed. Grassland areas are now regenerating [15, 35, 36] and analysis of satellite images reveals that forest accounted for 86% of the park in 1984 and 90% in 2003 (Fig. 6; [37]). Initially one would think that this environmental recovery to a "natural" state is the desired conservation goal as the forest that regenerates in this diverse matrix of habitats was converted in the first place. However, the replacement of the disturbed habitat by the original habitat may not always be the desired conservation outcome. In Kibale, some species that have adapted to use the disturbed habitat are not found elsewhere in the park. For example, the grasslands within Kibale support a population of African buffalo (*Syncerus caffer*) that do not prosper without access to grasslands. Similar declines have been documented with a number of bird species as the disturbed habitat is replaced by the original habitat [38-40].

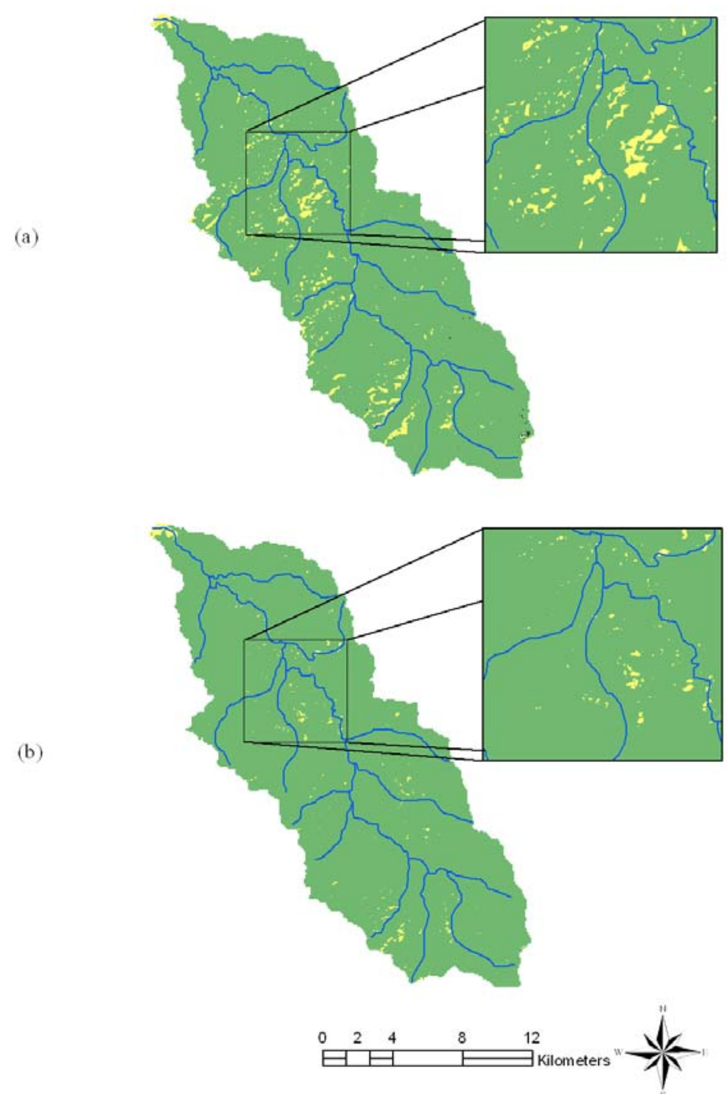

Fig 5. Increase in forested areas in the Rio Cuale Watershed, Jalisco, Mexico, from 1979 (a) to 2002 (b) (forest in green, agricultural land in yellow).

Evidence suggests that the small-scale disturbance in protected areas has potential benefits for the preservation of a diverse environmental matrix with high levels of local biological productivity. Many conservation policies have started programs of anthropogenic disturbance simulation to maintain habitat heterogeneity (e.g., Aggtelekk National Park, Hungary; Cadí-Moixeró Natural Park, Spain; Kakadu National Park, Australia; Grasslands National Park, Canada). Landscape managers and policy makers must consider both local and regional conservation goals when deciding to remove or maintain disturbance regimes that curtail ecological homogenization.

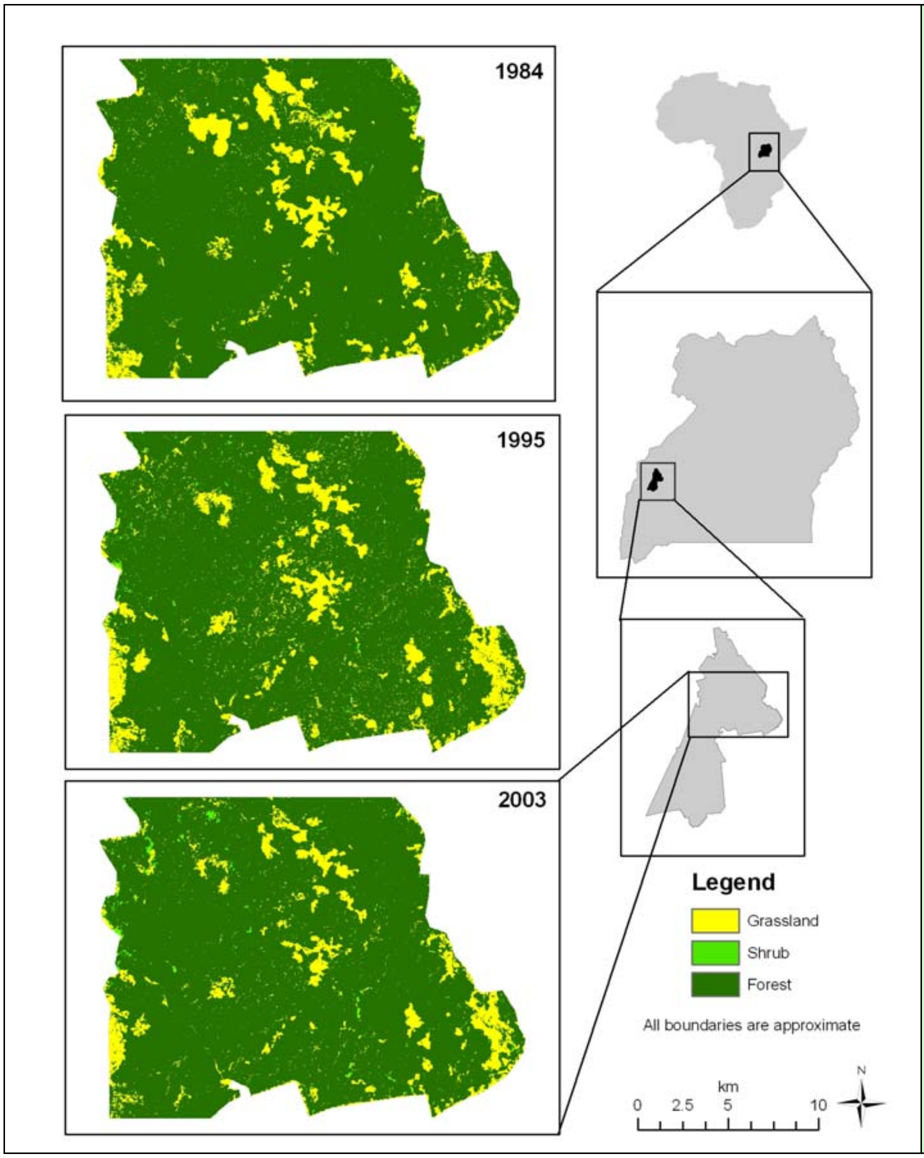

Fig. 6. Forest transition to grassland in Kibale National Park 1984-2003. Land cover assessment based on five-class supervised classification (89% overall accuracy, kappa statistic 0.867) from three dry-season Landsat Images (May 26, 1984, January 17, 1995, January 31, 2003) at 30m spatial resolution.

Action Agenda

We have illustrated that relationships can occur between declining fertility, increasing urbanization, rural abandonment, and environmental recovery/homogenization. The widespread existence of these demographic processes causing rural depopulation highlights the need for applied research that enables policy makers to respond to such changes in ways that would most benefit conservation and social and environmental justice. In this final section we draw attention to a set of research questions whose answers will be needed if policy makers are to respond appropriately to rural depopulation associated with urbanization and declining fertility rates.

1) Can a systematic global effort to assess the correlations between rural depopulation and environmental homogenization be developed?

From the data presented here it is clear that rural depopulation is a global trend and the examples suggest that under certain circumstances this will lead to environmental homogenization. However, when and where these processes will occur is not clearly understood. There are clear examples that it has occurred, but a global analysis linking rural depopulation and environmental homogenization is clearly required to make generalizations and to be able to move our understanding to a predictive stage. This is particularly clear with respect to the countries that we focused on. Spain, a temperate country, has large areas of depopulated land, and tropical/subtropical Mexico definitely has some rural areas that are clearly depopulating, while rural populations in most of tropical Uganda are still increasing. Understanding if, when, and where rural depopulation will occur in countries like Uganda will be a critical area of investigation if conservation managers are going respond to these changes.

2) What will direct depopulated areas into a process of ecological recovery or into plantation economies?

Once subsistence-oriented practices are largely abandoned in an area it will be critical to know what factors influence whether the land will enter into ecological recovery versus being integrated into an industrialized process, such as monoculture agriculture [41]. For large conservation gains to be made following rural depopulations, abandoned land must not be converted to another anthropogenic form of higher extractive pressure. In countries with high population densities, such as Uganda, it is possible that land abandoned by rural farmers relocating to urban centers will be converted to large-scale monocultures to provide products for export or urban markets (e.g., timber, biofuel, and tea), particularly in fertile agricultural areas. The potential increase in the use of crops for biofuels is one future that could result in large-scale monocultures with little biodiversity value [42]. It seems likely that factors such as topography, water availability, soil fertility, cost of development, and market accessibility will all play roles, but the relative contribution of these and other factors needs to be better understood to guide the action of policymakers. Research primarily from South America suggests that an understanding of economic drivers is essential to understand patterns of human movement, deforestation, and reforestation, and this research deserves special attention when attempting to understand drivers in other areas of the globe [9, 10, 41, 43, 44]. Butler and Laurance [45] argue that even if deforested and abandoned lands are taken over by major industries, this could provide conservation opportunities, because public pressure campaigns could have a strong influence on the fate of tropical forests,

3) What will determine the nature, speed, and direction of succession?
If rural depopulation occurs and land is abandoned it will become important to understand how to facilitate the regeneration of native vegetation [46, 47]. Unlike naturally disturbed areas, the regeneration of secondary forests on anthropogenically disturbed lands does not always follow predictable or linear pathways [48] and regeneration is often arrested [49, 50]. Understanding ways to break this arrested successional pathway and allow degraded lands to regenerate will become increasingly important as the amount of abandoned land increases. In addition it is important to acknowledge that degraded patches may have significant ecological importance, since transitional patches can contain high levels of biodiversity. Managers may need to develop strategies to keep areas from full regeneration/homogenization, which might involve maintaining a disturbance regime or even encouraging human use of lands.

Arroyo-Mora et al. [44] conducted a landscape analysis for forest cover from 1960 to 2000 in the Chorotega region of Costa Rica. They documented that the period between 1980 and 2000 was one of secondary forest growth, but that the landscape was still highly fragmented at the end of the study. This indicates that the process of homogenization can be very slow, and the response of specific species during this period of slow transition will likely be determined by the scale over which they move and their ability to use this secondary forest.

4) Can national economic trends predict migration patterns and human pressures on rural areas?
Urbanization is highly correlated with economic development. The current global economic system, characterized by hyper-mobility of capital, factories, and commodities, does not, however, foster stable industrialization and urbanization patterns [51, 52]. Contemporary global markets encourage “boom and bust” cycles of sudden industrialization, urbanization, and collapse, which promote migration waves back and forth to rural areas. Further analysis of national economies may predict internal migrations patterns and, therefore, land abandonment with the subsequent opportunities for environmental recovery and vice versa. The understanding of economic cycles and their impact on migration movements may help predict conservation threats and opportunities, or may lead to means of discouraging “boom and bust” cycles, important for improving the economic security of local inhabitants and conserving the environment.

5) How can conservation gains be made from declining rural populations in a socially responsible way?
In environments with little capacity for agricultural industrialization, there should be space for mutually beneficial land-use agreements between policy makers and farmers or ranchers. Today when agricultural subsidies are receding, conservation policies can become the new source of subsidies and incentives for human communities at the margins of the national productive structure. However, there is a paucity of field tests of successful incentive-based conservation programs [53]. Comparative analyses of the factors promoting success in incentive-based conservation programs would greatly facilitate the ability to reach conservation goals on depopulated rural lands.

Implications for Conservation

Admittedly, the depopulation of rural areas and habitat regeneration is just one possible future and different regions may take different tracks. However, given current global trends and the widespread occurrence of rural depopulation that is already evident, we feel there is an urgent need to consider how to manage depopulated rural lands and believe our analyses illustrate a potential future for many regions. Furthermore, managing depopulated rural areas offers new ways of portraying conservation biology. Too often conservation is viewed as relaying stories of doom and gloom. Taking additional (and perhaps non-traditional) approaches that focus on restoration of lands offers exciting grounds for optimism, stimulating avenues for future research, and means to engage the public. In addition, conservation in depopulated areas may offer an additional source of benefits to local populations under high levels of stress. To achieve social and environmental justice, however, local populations must be included in the decision-making processes associated to conservation.

Acknowledgements

Funding for this research was provided by Canada Research Chairs Program (CC), Wildlife Conservation Society (CC), and Natural Science and Engineering Research Council (AJ, CC, RS). We thank Lauren Chapman, Colin Shanley, and two anonymous reviewers for helpful comments on this research. We thank Jane Southworth and Mike Binford for help with the image of vegetation change in Kibale, and Paula Bauche for the work on the image of Rio Cuale Watershed, Jalisco, Mexico.

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