Secondary biodiversity and agriculture: definitions and threats from global change

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# Abstract

Primary biodiversity can be defined as the biodiversity of still remaining pristine wilderness areas of the World. Sparsely populated countries, mostly in the New World (Americas, Australia), possess vast such areas. In densely populated countries of the Old World, however, the situation is very different. Here virtually all nature is modified by past and present human activities. The biodiversity, although high in these countries (Japan, Europe), is mostly of secondary nature. The main threat to primary biodiversity is human impacts; contrariwise, the main threat to secondary biodiversity appears to be abandonment of farms and ceasing land management – mostly demography-driven factors that affect both local agriculture and natural processes. Many developing countries, typically members of ASEAN, possess vast areas with primary biodiversity as well as large agricultural areas with valuable secondary biodiversity. Preserving primary biodiversity in Mega-diversity countries is a clear priority; however, intensification of lowland agriculture and abandonment of subsistence farms in highlands, depopulation of rural areas due to migrations to industrial and commercial centers can lead to major land use changes and threaten traditional man-made landscapes with high conservation value. Consequently, the threats to secondary biodiversity in developing countries must not be overlooked.

**Key words**: *Natural biodiversity; Agricultural biodiversity; Land-use change; Farmland abandonment; Landscape management*.

# Introduction

Agriculture and biodiversity are tightly related. There are at least three major areas of research and development where interactions between agriculture and natural biodiversity have important consequences to our life. First, agriculture is derived from natural biological diversity. Indeed, only species with a particular set of traits could be domesticated (Diamond 1997). For plants as an example, this special set of traits, or domestication syndrome, includes: (1) high germination rate, (2) predictable and synchronous germination, (3) retaining ripe seeds till harvest, (4) reduced physical and chemical defenses, and (5) biomass allocation suitable to our benefit. Clearly, the higher the biodiversity, the higher the chances to find plants with domestication syndrome, and thus we arrive to the second area of interactions between biodiversity and agriculture, which is grasped by the concept of agricultural biodiversity. As it is defined in the report from the Food and Agriculture Organization of the United Nations (FAO 1999), agricultural biodiversity “encompasses the variety and variability of animals, plants and micro-organisms which are necessary to sustain key functions of the agroecosystem, its structure and processes for, and in support of, food production and food security”. A broader view can also include not only genetic and species variability, but also the diversity of communities, ecosystems, landscapes, as well as all kinds of human activities that affect these components of agricultural biodiversity (Jackson et al. 2005). Finally, the third area of intersection between biodiversity and agriculture is very important to nature conservation. The problem is that land-use development for agricultural purposes is becoming a main global threat to natural biodiversity through the worldwide changes to forests, farmlands, waterways, coastlines, and air (Millennium Ecosystem Assessment 2005; Turner 2nd et al. 2007). Hence, careful designing of agricultural development becomes important tool in nature conservation.

The aim of this study is highlighting the strongly different approaches to conservation of natural and agricultural biodiversity among countries. These approaches and their realization depend on the differences in the population density, the level of agriculture development, the geography and history of the nations. In particular, to demonstrate the differences in national conservation priorities, here I analyze the dependence of certain environmental indices on population density and agriculture development, and compare the role of human management in ongoing conservation efforts among countries. I also argue that the observed differences are profound and thus deserve special definitions as to what kind of biodiversity conservation is addressed.

# Methodology

The main approach of my methodology is comparative analysis to reveal national differences in the theory and practice of nature conservation. I used various data from open-access worldwide databases on economy, agriculture, demography and environment of countries (NationMaster.com). The following indices were analyzed.

Country Wildness index was defined as percent of land area having very low anthropogenic impact. Data were taken from Global grids for population (GPW), land use (USGS AVHRR based classification from EROS data center), VMAP roads, VMAP railways, VMAP coastlines, VMAP major rivers and the stable lights data were all scored for "wildness". The scores were aggregated and normalized (Chape et al. 2003, as cited in NationMaster.com).

Country Biodiversity richness was defined after Caldecott et al. (1994) (as cited in NationMaster.com).

Population density represents number of inhabitants per km2 (as cited in NationMaster.com)

Gross Domestic Product (GDP) was measured as Purchasing Power Parity (PPP) in Millions of International Dollars, 2004 (as cited in NationMaster.com).

Number of tractors was measured as the number of tractors in use and refers to the total number of wheeled and crawler tractors used in agriculture in 2000. Garden tractors are excluded (as cited in NationMaster.com).

Tractor concentration was measured as the number of tractors per 1000 ha of cropland. This was calculated by World Resource Institute (WRI) by dividing the number of tractors in use by the total hectares of arable and permanent cropland. Data for agricultural machinery are reported by country governments through surveys. Individual countries have different methods of data collection (as cited in NationMaster.com).

Trend analysis was performed using software Statistix9 (Tallahassee, Fl. USA).

# Results and discussion

Wilderness is a special value in biological conservation – historically, preservation of areas with natural environment that has not been significantly modified by human activity, was and is one of the principal priorities of national and international nature conservation programs (Aplet et al. 2000). Yet, the nations differ strongly in their history, geography and development – consequently, their potential for wilderness conservation also varies considerably. The Wildness index - percent of land area having very low anthropogenic impact – highlights this variation among countries (Chape et al. 2003). It is easy to imagine that that population density of a country will affect its wilderness – indeed this global trend appears to be strong so that the variation in population density explains over 60% (R² = 0.632) of the variation in Wildness index (Fig. 1). However, the trend is far from being uniform and countries can find themselves in fairly different situation with respect to biodiversity. For instance, Japan, South Korea and Bhutan show 0 or nearly 0 levels of Wildness index, although population density of these countries differs more than 10-fold (Fig.1, note that X-axis is shown in logarithmic scale). On the other hand, Algeria possesses over 80% of Wildness index in spite of having the same population density as Bhutan (Fig. 1). These within-trend variations are explicable: Japan and South Korea are highly industrialized and very densely populated nations – no area was left there without strong human impact. Bhutan does not have any sizable industry, and agriculture is mostly represented by subsistence farms. Despite of its low density, Bhutan’s population is evenly distributed, so that human impact, even though moderate, spreads all over the country (Wangda and Ohsawa 2006). Unlike Bhutan, Algeria’s population is concentrated along coastal area leaving vast territories of Saharan sand desert nearly void of human population – hence very high Wildness index (Cantú-Salazar and Gaston 2010). Fortunately, the conservation potential of nations does not depend solely on wilderness; otherwise countries with high population density will always be inferior in this respect. Indeed, in reality Japan’s Biodiversity richness index is ranked among the highest (Caldecott et al. 1994)! And this is despite of the fact observed above that Japan’s Wildness index is nearly 0 (more precisely, equals to 0.06%, see also Fig. 1). If there is no (or very low) wilderness, then where Japan’s biological diversity is conserved?

The secret is in the Japanese traditional agricultural system, implementation of which started back in 1666 under Shogunate governance (Diamond 2005). This type of forestry and agriculture is defined as Satoyama, a main feature of which is sustainability: strict rules prevented any overuse of natural resources and thus supported overall sustainable development of agriculture-based economy (Takeuchi and Brown 2003). Satoyama can be understood as an integral rural landscape: a network of forests, rice paddy fields, dry fields, grasslands, streams, ponds, and water pools for irrigation. Forest management is based on selective logging or 15-20 years rotational logging of planted coniferous (mostly Pine *Pinus densiflora*) and broad-leaved tree species (mostly deciduous oaks *Quercus acutissima* and *Quercus serrata*); these managed forests provide construction timber and fuel wood, while certain amount of timber, fuel wood and fertilizers (litter) are taken from village-owned coppice forests. Farmers manage the grasslands as pastures for horses and livestock. Streams, ponds, and reservoirs play an important role in regulating water levels of paddy fields and farming fish as a food source (Kobori and Primack 2003). Most importantly, Satoyama provides excellent habitats for wildlife and many plant and animal species are able to live in the planted forests owing to traditional management practices. Wild animals can migrate across landscapes through ponds, rice paddies, grasslands, forests. Freshwater ponds, pools, streams provide habitat to various water-dependent insect species and thus maintain important food webs to support bird and insectivorous fauna (Takeuchi and Brown 2003). Managed (semi-natural) grasslands maintain considerable pool of herbaceous species with high conservation value (Kitazawa and Ohsawa 2002; Kawano et al. 2009).

However, today this important pool of biodiversity is under the threat of disappearance. This is the consequence of the radical changes in the demographic structure of Japan: aging and depopulation of rural areas due to industrialization and urbanization (Fukamachi et al. 2001). Indeed, Japan possesses second highest number of tractors after the U.S.A. (Fig. 2); at the same time the concentration of tractors in Japan reaches 420 which is third in the World after Iceland (1288) and Slovenia (560). As modern Japanese agriculture depends more on mechanisms and chemicals but less on human labor, traditional landscapes are increasingly abandoned (Morimoto and Yoshida 2003; Takeuchi et al. 2003). As a result of abandonment and ceasing management, biodiversity of secondary forests degrade strongly, and this threat has been recognized by Japanese government and society by the end of last century. Japanese government outlined “The third national conservation strategy of Japan” (Government of Japan 2007) where conserving Satoyama and traditional landscapes is one of the principal aims. At present, numerous non-profit, non-governmental environmental groups work for the conservation of Satoyama (Takeuchi et al. 2001).

Similar trends can be found in other post-industrial countries. For instance, the rapid abandonment of montane hey meadows in Switzerland is linked to dramatic decrease in the biodiversity of these traditionally managed meadows (Stampfli et al. 1994; Stampfli and Zeiter 2001). Another example is sustainable traditional agroforestry system – Dehesa – developed in Spain and other countries with Mediterranean climate (Joffre et al. 1999); abandonment threatens high biodiversity supported by Dehesa (Fra Paleo 2010). Governments of these countries, as well as European Union, enlist conservation and management of traditional landscapes as important goals for their conservation strategies (e.g., European Union 2011). These strategies highlight the importance of landscape management that is oriented to conservation of traditional scenes but not to agricultural output.

# Conclusions

Biodiversity can be high not only in the wild, but also in man-made semi-natural systems. It is remarkable however, that biodiversity in semi-natural systems declines after the withdrawal of humans from the system. This is contrary to wilderness where avoiding human presence symbolizes the main measure of protection. This evident dissimilarity prompts us to a differential conceptualization of biodiversity conservation. We can define the biodiversity of still remaining pristine wilderness areas as Primary biodiversity. Conservation of Primary biodiversity is the main priority for relatively sparsely populated countries, which possess vast areas of wilderness. In densely populated countries, however, the situation is very different. Here virtually all nature is modified by past and present human activities, although high biodiversity is maintained. This type of biodiversity can be defined as Secondary biodiversity. Conservation strategies for these two types of biodiversity can be based on landscape management, although with the opposite aims: in case of Primary biodiversity the landscape shall be maintained by avoiding human activities such as economic/agricultural development; on the contrary, in case of Secondary biodiversity the aim of landscape conservation appears to be preventing the consequences of farm abandonment and ceasing land management.

Many developing countries, typically members of ASEAN, possess vast areas with Primary biodiversity as well as large agricultural areas with valuable Secondary biodiversity (Mittermeier et al. 1997; Conservation International 1998). Preserving Primary biodiversity in these mega-diversity countries is a clear priority; however, ongoing industrialization, urbanization and intensification of lowland agriculture potentially can lead to abandonment of subsistence farms in highlands and depopulation of rural areas. Thus, the history can repeat and threaten traditional man-made landscapes with high conservation value. Consequently, the threats to Secondary biodiversity in developing countries must not be overlooked.

# Acknowledgements

I am grateful to Prof. Dr. Y. Purwanto for very inspiring discussions.

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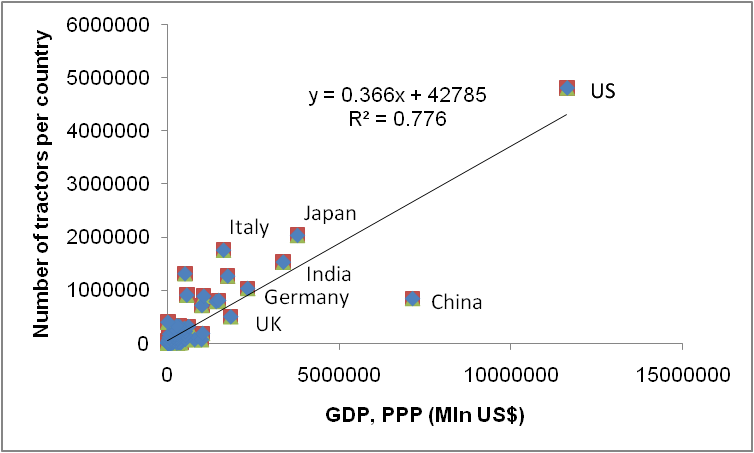
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**Figure 1**. Global trend in the dependence of country Wildness index (Percent of land area having very low anthropogenic impact) on country population density (note that X-axis is in logarithmic scale).



**Figure 2**. Global trend in the dependence of the number of tractors on GDP measured as Purchasing Power Parity (PPP in Millions of International Dollars, 2004) per country.