Livestock, land use change, and environmental outcomes

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Introduction Rapid predicted worldwide growth in demand for animal products to 2020—the so-called "next food revolution" in animal agriculture—portends complex interactions among people, biological and geophysical resources, and economic objectives. A restructuring of global food demands is expected: in contrast to current patterns, most (>60%) global production of meat and milk will be consumed by households in the developing countries (Delgado et al., 1999). The key drivers of this change are income growth, population growth, urbanization, and increased opportunities for trade. We identified some of the environmental risks, and recuperative effects, of animal agriculture in a recent article (Nicholson et al., 2001). This presentation focuses more broadly on the ecosystem impacts of conversion of land to agricultural uses, concentrating on systems with ruminant livestock, the linkages to growth in animal products demand, and priorities for policy and research. Two key questions are "How can (should) international agricultural researchers, the development community, and policy makers support the beneficial aspects of the growth in demand for animal products while minimizing negative environmental outcomes?" and "Who should pay for changes to agricultural systems to reduce or mitigate environmental impacts?" The answers to both these questions are likely to be site-specific due to differences in biophysical settings, values, and political realities.

Ecological and environmental impacts of land conversion Increased livestock production has a number of potential negative environmental consequences. Among these, the conversion of land from natural habitats to agricultural uses more generally—particularly in tropical forest areas—has been a key cause for concern for the past few decades. Land use conversion from forest to pasture is driven by incentives for livestock production (which are increased by livestock demand), limited alternatives to livestock production in these areas, and perhaps more importantly, economic inequality and poverty that create incentives for forest clearing by migrants. Clearing forest land reduces biodiversity and ecosystem services (e.g., pollination, pest control, flood control and water release). Various forecasts, differing in degree but not in direction (Laurance et al., 2001; Tilman et al., 2001; Vitousek et al., 1997), anticipate important losses of habitat, biodiversity and ecosystem services by transforming more land to feed humankind, especially in Latin America and sub-Saharan Africa. These environmental modifications can affect sustainability (and economic returns) in a variety of agricultural systems. However, the extent of these long-term effects often is not well-documented or acknowledged.

Responses in habitat loss and fragmentation Simplifying natural ecosystems for agricultural use can lead to species losses and substitutions. Many poorly understood factors and interactions influence biodiversity outcomes in low and high rainfall ecosystems. Burning is a principal pathway for initial forest clearing and routine pasture management in many parts of Latin America. Less pasture burned less frequently would protect forests and the services they provide. Lost and fragmented habitats make it more difficult for plants and animals to meet needs and survive environmental vagaries (Laurance, 2001; Sala et al., 2000).

Cascading effects on species shifts and biodiversity losses Transforming lands with marginal fertility to agriculture can have a large global effect because these locations sustain ecosystems of high diversity. About 18% of mammals, 11% of birds and 8% of plant species may currently be at risk of extinction from land conversion, which implies significant agroecosystem losses such as wild genes for resistance to plant pests and disease, pollination by birds, insects, bats and other mammals (from neighbouring ecosystems), and pest outbreak control by predators. Scarce soil nutrients are more completely utilized in high diversity systems, which constitutes a barrier to invading species (Western, 2001). Conversely, unconsumed nutrients may favour pathogens and pests, which may be a consequence of indiscriminate or uncalibrated fertilisation of food and forage crops. Species extinction is partly governed by the interaction between dispersal ability, habitat loss and climate change, including greater rainfall variability.

Agroecological options An important agroecological goal in the long term is to assure sufficient land and resources for survival of most species. This requires learning how ecosystems interact with, and recover from, environmental disturbances, including agriculture. It also means curtailing the cascade of impacts on habitats, species numbers, ecosystem services, and nutrient stocks. However, achievement of this objective will require economic incentives, especially for small- and medium-sized farmers who are our key environmental stewards (Pinstrup-Andersen, 2001).

Pasture-based cattle production in Brazil's *arc of deforestation*: issues and information needs The Amazon region of Brazil is home to about one-fourth of the national herd of ~170 million cattle, which is currently reared extensively on ~43 million hectares. Forest losses are especially high in the four-state "arc of deforestation" including westernmost Acre State (Cochrane, 2001). Current trends suggest more habitat fragmentation, less rainfall from less evapo-transpiration and sequestered atmospheric moisture from smoke, higher land surface temperatures, species losses, and heightened risk of forest fires. Although widespread pasture degradation is well documented in the eastern Amazon, the farm management practices (e.g., stocking rates, soil-plant nutrient relationships, burning frequencies) causing it have not been adequately studied.

Recent studies explored soil-plant-animal nutrient relationships, milk and beef potentials, and economic constraints of pasture-based cattle systems in Acre, where large fire-managed paddocks are lightly stocked with animals not differentiated by nutritional requirements. Findings indicated relatively low nutrient exports in animal products of 6 kg N/ha and 3 kg P/ha (compared to rice, beans or coffee crops) from farms with two 450-kg animal units per hectare (Rueda et al., 2002a). In contrast to studies in the eastern Amazon, pasture productivity has been maintained for two decades. This relative longevity may result from better soil characteristics than elsewhere in Amazonia, but also from low stocking—which results in more-than-adequate pasture biomass availability, substantial nutrients recycled from leaf litter and less soil compaction. This evidence supports the idea that pasture management may play a key role in system sustainability.

Although the current cattle production system in the western Amazon appears sustainable, improved access to regional and international beef markets could imply the need for intensification to reduce additional forest clearing. Substantial productive potential was identified for application of external nutrients to pasture to increase stocking rates and offtake. This translated to greater net economic returns from labour-intensive (i.e., potentially land saving) technologies to produce beef (but was not profitable for milk), and not by improving individual performance by better supplementing diets (Rueda et al., 2002b). However, the long-term dynamics of this intensification strategy are not known. Higher stocking rates imply shifts in the pools of nutrients to recycle from plant litter to readily decomposable animal excreta. To explore the potential impacts, a systems modelling approach can be useful.

Conclusions More understanding is needed about the interaction of agricultural practices with environmental and ecological outcomes to develop practices that avoid further deterioration and restore accumulated damages. Integrated agroecological strategies include improved nutrient management, illustrated above for the western Amazon and bridging (restoring) forest fragments with hospitable fence line corridors and windbreaks of native species to facilitate wildlife dispersals and ecosystem services. The main challenge involves connecting existing knowledge about how agroecosystems function to the effectiveness of candidate interventions in specific situations. Multidisciplinary systems modelling efforts can help to identify "high leverage" interventions to achieve agricultural and environmental objectives.

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