Global effects of changing land-use on animal agriculture

D. Tolleson* and P. Meiman†

*University of Arizona, School of Natural Resources and the Environment
†Colorado State University, Department of Forest and Rangeland Stewardship

Implications

- Proper science-based land and livestock management will continue to mitigate negative environmental effects of livestock production, and provide positive effects, while producing needed goods and services.
- Global effects of changing land use on animal agriculture are diverse and vary regionally.
- Decreased productivity of animal agriculture results from:
  - Direct and indirect loss of productive land to support animal agriculture.
  - Shifts in societal emphasis away from production.
  - Socio-political disruptions, especially armed conflict.
- Increased productivity of animal agriculture may result from:
  - Innovative ways to increase land area available for animal production.
  - Enhancing productivity of land currently used for animal production.
  - Targeted or prescription grazing (e.g. at the wildland-urban interface).
  - Development of small holder operations in urban areas.
- Global changes in land use present multiple challenges to animal and rangeland scientists. The need to mitigate negative impacts, enhance positive impacts, and discover new innovative contributions to society from animals is at a critical juncture.

Public Focus on Negative Impacts of Animal Production

“Income is projected to continue to rise in all three North American countries. The faster growth of income in developing countries worldwide will lead to continued growth in demand for animal source foods…”

“Despite improvements in technologies, manure management and new regulations, by-products from animal agriculture production and processing can still result in negative impacts on the environment…”

Both of the above quotes are from a 2004 publication by the Farm Foundation: The Future of Animal Agriculture in North America. Additionally, Abdalla and Lawton (2006) in their discussion of environmental issues in animal agriculture, state that:

“Farmers are traditionally viewed as good stewards of the land and the environment, and enjoy a large amount of good will among the public. The public may be less tolerant of environmental and nuisance impacts of animal agriculture, especially larger units. Improved scientific understanding of the impacts certain management practices have on the environment and human health may change public perceptions.”

The excerpts above indicate that animal agriculture is at an interesting juncture in our modern world. Animal products are needed and desired but are obtained at economic and environmental costs. Domestic animals have cultural and religious importance to some while others are apathetic or antagonistic toward them. The Food and Agriculture Organization of the United Nations reports that...
the United Nations (FAO)-published document, Livestock’s Long Shadow (Steinfeld et al., 2006), is an example of the dichotomy that exists in the world with respect to livestock production. Hailed by some as the final word on livestock production being the greatest environmental threat wrought by humans; it is also decried by others as environmentalist propaganda. The authors take a critical look at the impact of livestock production on the environment and present opportunities to mitigate those effects through sound management. It does not in our opinion, however, balance the negative aspects of animal agriculture with the positive aspects. Nor does it discuss the negative impacts that changing land use and other parameters have on animal agriculture and thus, society’s ability to efficiently and sustainably produce livestock products. The purpose of this article is not to confirm or refute statements in Livestock’s Long Shadow [Pitesky et al. (2009) is a suggested source for such information]; it is simply used here as an illustration of the topic at hand. We would like to emphasize that the non-agricultural public is typically not provided with information about the positive effects of animal agriculture. Unfortunately, those who have negative views of animal agriculture are well funded and media savvy. Therefore, we have provided below a brief commentary on the positive contributions to global society by animal agriculture and animal source foods or by-products. For those who wish to dig deeper, we suggest Bradford (1999), who wrote an excellent review on how animal agriculture will contribute to human food needs in the future.

**Societal Benefits of Animal Agriculture**

**The role of animal source foods in human health and nutrition**

Many human nutritionists suggest that one should eat a balanced diet that includes a variety of meats and dairy, vegetables, grains, fruit, and nuts. The human body is 20% protein by mass. Amino acids are the molecules from which proteins are constructed. Some of these are classified as essential; i.e., we must obtain them from our diet. Animal proteins supply a complete source of amino acids (including the essential ones) and are more easily digestible than plant proteins. This does not mean that one cannot obtain a balanced amino acid diet from plants; it just requires a more conscious effort to do so. Such a task is easy to accomplish in developed nations for middle class and wealthy families or individuals. It is more difficult for those in challenging economic circumstances.

Meat, fish, and other animal source foods such as milk are the only natural sources of vitamin B12. In fact, red meat contains several B vitamins. Meat is also a good source of iron and zinc. Additionally, meat and milk contain fat. Although there seems to be an entire industry devoted to combating fat, fat in proper amounts and composition is an essential part of a healthy diet. Fat is a concentrated source of energy, facilitates maintenance of core body temperature, and provides for absorption of fat-soluble vitamins (A, D, E, and K). Fat tissue in the body also plays an important role in healthy endocrine and immune function. Although we normally think of foods when we think of animal products, benefits to humans from livestock are not restricted to foods. Many indigenous peoples had a use for every part of the animals they consumed. Such is also the case today. For instance, replacement heart valves for humans may come from pigs. Heparin to prevent blood clots is derived from domestic animals. Gelatin is also an animal by-product. Animal fiber such as wool, mohair, or cashmere come from sheep and goats and sometimes other species such as camels, llamas, and yaks. These products are important economically. The United Kingdom in 2014 sold over £21 million of beef offal to non-European Union markets alone, a 35% increase over 2013 (AgriLand 2015). Cashmere products are Mongolia’s sixth largest export behind coal, copper, iron, petroleum, and gold. Most of us know that livestock manure is useful as a fertilizer. There are probably fewer, however, who know that this material is used as a household fuel in Mongolia and a building material in many parts of Africa.

**Interrelationships with wildlife ecology and management**

Aldo Leopold, the father of wildlife conservation in the United States (US), said that the same tools used to destroy wildlife habitat (e.g., the cow, plow, ax, match, and gun) can also be used to preserve it. For instance, the Edwards Plateau of central Texas (US) was heavily grazed around the turn of the previous century (Franklin and Brand, 1991). Livestock numbers were reported as high as 80 to 150 animal units per 640 ac (260 ha) compared with current estimates of 25 to 40. As was common during the early 1900s, fires were typically suppressed. This combination of heavy grazing and absence of fire shifted the predominant vegetation type from tallgrass prairie with scattered mottes of oak and juniper to a landscape dominated by dense stands of juniper with a shortgrass understory. This was not a land-use change as we are applying the term here, but it was certainly a change in how these rangelands were managed. Carrying capacity for livestock and wildlife decreased as did biodiversity. In the 1950s, the Texas Game and Fish Commission (now Texas Parks and Wildlife Department) obtained the Kerr Wildlife Management Area southwest of Mountain Home, TX, and since that time have implemented brush control, prescribed fire, and rotational grazing. These practices have benefited game species such as white-tailed deer and turkey and endangered non-game species such as the black-capped vireo. Additionally, Krausman et al. (2009) provide three case studies of how well-managed livestock grazing can be used to benefit habitat for grassland birds in South Dakota, elk in Montana, and small mammals in Pennsylvania riparian habitats. Cattle herding practices in Kenya, i.e., bringing livestock into enclosures (bomas) at night, caused nutrient enriched grassland patches that were beneficial to livestock and wildlife, particularly impala, for many years (Augustine, 2004). These are but a few examples of synergistic management for domestic and wild animals in grazinglands around the world.
Impact of animal source foods for disadvantaged women and children

Livestock play critical roles in general nutritional health, immunity, and economic standing for women and children in developing nations. For instance, Oluwatayo and Oluwatayo (2012) write:

“Because of the high poverty level... Rearing of small ruminants plays a very important role in the lives of households in developing countries. This is because small ruminants provide the easiest and most readily accessible source of credit available to meet immediate social and financial obligations. In southwest Nigeria, for instance, rural women are involved in the raising or rearing of small ruminants—sheep and goats especially around homes by feeding them kitchen wastes or at most times leaving them to graze on surrounding herbs and shrubs.”

Similarly, a research group led by the UCLA School of Medicine (Neumann et al., 2003) report that:

“The inclusion of ASF’s (animal source foods) in the diet has been shown to promote growth, cognitive function, physical activity and health. The relatively high fat content of ASF’s increases energy density, which is particularly useful in young children, given their relatively small gastric volume. Milk and other dairy products and meat provide high-quality, readily digestible and complete protein containing all the essential amino acids (Williamson et al., 2005). The need for ASF’s is particularly important during pregnancy when iron, zinc, calcium, vitamin B12, folic acid and high quality protein are necessary to support maternal nutritional needs, fetal growth and development, and preparation for lactation (Allen, 2005). ASF’s are important complementary foods in preschool and school-aged children for supporting optimal growth and development, physical activity and behaviors conducive to learning (Grantham-McGregor and Ani, 1999; Neumann et al., 2002; Black 2003).”

So yes, improperly managed livestock production has and will continue to result in negative environmental impacts. Properly managed, science-based livestock management (and inherent to this, land management practices), however, can and will continue to mitigate negative effects, and/or provide positive effects—all while producing the important agricultural and ecosystem goods and services described above.

Effects of Global Land-use Changes on Animal Agriculture

Now that we have set the stage for our discussion, we will start with more obvious effects of changing land-use and then proceed to those perhaps less well known in the US but equally impactful. First is the direct loss of productive land once used for animals or used to provide feed for animals. Spanish scientists (Benayas et al., 2007) examined occurrences of agricultural land abandonment worldwide. Among the major effects they report are: loss of biodiversity, increasing intensity or frequency of wildfire, and decreases in cultural and/or aesthetic values. These impacts were not equally relevant in all regions. Consistent with our leading discussion, the authors state that the abandonment of agricultural land may also be beneficial in some cases. Included among the benefits they report are: passive revegetation and active reforestation, soil recovery, and improved nutrient cycling.

Effects of an increasing global population—‘we need more room’

The most intuitive form of direct land loss affecting animal agriculture and/or management of natural resources comes as the result of residential development or urban sprawl. This effect is often closely linked to changes in population. In the US, development (urban and other forms) is expected to increase by 41 to 77% between 2010 and 2060 (USDA Forest Service, 2012) and would likely have significant impacts on the land area available for animal agriculture. Land-use changes in the recent past provide some indication of potential impacts. For example, between 1982 and 2007 on private or state land in the US, the total area of cropland, pastureland, and rangeland declined by 63 (25.5), 12 (5), and 9 (3.6) million ac (hectares), respectively (USDA Forest Service, 2012). Specifically, the Phoenix, AZ metropolitan area (largely agricultural for centuries) has experienced exponential growth in urban cover with an accompanying decrease in agricultural lands (Jenerette and Wu, 2001; Fig. 1). These agricultural acres were not only devoted to cotton and citrus crops, but included alfalfa and grain fields as well, thus affecting sources of feed for primarily beef and dairy cattle. These trends are not limited to the US and are actually expected to be more pronounced in developing than developed countries. Worldwide from 1980 to 2003, annual urban population growth was 3%, with the majority of that occurring in developing countries (FAO, 2009). The same source reported that meat production worldwide has more than doubled over that same time period, with the vast majority of the increased production occurring in developing countries and in the form of poultry and swine, while there have been negligible increases in the production of cattle, sheep, and goats worldwide and, interestingly, no increase in developed countries (FAO, 2009).
One interpretation of these trends is increased efficiency (i.e., more meat produced from presumably less land area worldwide). Such interpretations are hard to deny although increased efficiency may not necessarily be optimal. It is probably quite safe to say that most swine and poultry production is intensive while ruminant (cattle, sheep, and goat) production systems can be, and often are, more extensive. Societies should carefully consider both intensive and extensive meat production options to arrive at the mix that is most appropriate. Given the fact that domestic ruminant production can be managed in ways that maintain or improve the ecological condition of grazinglands (both pastureland and native rangeland), some degree of efficiency should probably be forgone in exchange for a sustainable land use that can support livelihoods, communities, and ecosystems. This idea has recently been developed to the point that Knight (2007) proposed, and effectively described, ranchers as a keystone species in a West that works. So with regard to changing land use, it would seem that the challenge for the animal agriculture industry and for scientists in particular is a paradoxical one; how do we mitigate the effects of an increasing urban population that just so happens to be the consumers of our product?

**More room to play and/or pursue a chosen lifestyle**

The next effect to consider is that of increased recreation occurring on pasture and rangeland. The demand for ranchland by individuals who are not primarily interested in animal agriculture as a business and who are willing to pay higher prices for that land as opposed to prices paid based on livestock productive capacity is another direct loss of land for animal production. Much of this type of development is more dispersed and farther from urban areas and often referred to as exurban growth. Commonly, recreational opportunities are closely linked to demand for such land, especially in areas that are considered high amenity (e.g., close to public land with recreational opportunities). A recent study of three state counties in the US (one each in Colorado, Wyoming, and Montana) reported that more than half of the ranchland that changed hands in those counties between 1990 and 2001 was purchased by “amenity buyers,” while only around 13% was purchased by traditional ranchers (Gosnell and Travis, 2005).

As urban and exurban (i.e., outside a city) development increases, social and political dynamics of formerly rural and agricultural-focused communities can be expected to change, which may result in significant implications for animal agriculture. Indications of these differences were reported by Mealor et al. (2011), who surveyed exurban landowners from six Wyoming counties to represent exurban landowners in that state. Sixty percent of Wyoming exurban landowners in that study reported that they had no prior experience managing land, and 96% reported that less than 10% of their annual household income was derived from activities on their land (Mealor et al., 2011). Only 1% of respondents reported that their annual income was from agriculture (Mealor et al., 2011). Rather than earning a living from their land, the exurban landowners in that study identified enjoyment of the rural lifestyle, aesthetic values, and open space as their main reasons for buying their land (Mealor et al., 2011). Across the West, it appears that a vast majority of exurban landowners are much more focused on land amenities than on agricultural production (Mealor et al., 2011; Gosnell and Travis, 2005; Lage, 2005). It should be noted that some of these new “ranchers” may continue to produce livestock on their lands, but others will not. The effect that the proportion of new landowners that do or do not produce livestock, as well as the pace at which these novice producers acquire and apply knowledge in their livestock production activities, is yet to be determined.

Outdoor recreation is one of the multiple uses for federally owned public lands in the US. Continued increases in recreation pressure on public lands is expected, especially adjacent to large urban centers (USDA Forest Service, 2012). In addition, these are the areas most likely to experience urbanization and exurban development, which can change attitudes toward land management. Much animal agriculture in the western US is dependent on public land grazing allotments. One potential outcome, and one observed by both authors, is the change in focus of public land management to include increased emphasis on recreation. This is not unexpected. There are certainly more outdoor recreationists than farmers or ranchers and more urban dwellers than rural ones. This fact is surely not lost on agency personnel or elected officials. And as described above, even the rural population is becoming more recreation or lifestyle oriented than production oriented. Depending on one’s perspective, this occurrence might be viewed as either a necessary change toward a better balance of multiple land uses or a movement that does not bode well for the future of animal agriculture. One thing is certain: livestock producers in parts of the western US are finding that this described change in demographics and perspective have made it a much more difficult environment in which to operate. Livestock grazing permits on public lands have declined in recent years. Ironically, outdoor recreation was identified as one of the leading threats to endangered plants (Rankin et al., 2015), while well-managed livestock grazing maintains or improves ecological function, and ranching was identified as the most ecologically sustainable segment of the US meat industry (Sayre et al., 2012).

It is important to recognize that outdoor recreation and animal agriculture do not necessarily conflict and in fact are often very complimentary or even synergistic. Many ranches and ranchers operate sizeable hunting or other recreational enterprises as part of their operation (see discussion by Sayre et al., 2012). Further, a survey by Utah State University found that more than 50% of hunters and about 33% of hikers felt that seeing cattle in a US national monument was either neutral or added to their experience (Brunson and Gilbert, 2003). So while hikers were less amenable to cattle than hunters, only about 33% of hikers also said that multiple use (which includes grazing) detracted from their outdoor experience. Visitors to US national monuments may be less accepting of livestock than those who recreate on other federal public lands. Mitchell et al. (1996) surveyed nearly 1,000 visitors to a national forest in western Colorado over a 2-yr period and

![Elk and cattle present at a water source on University of Arizona’s V Bar V Ranch](source: Dave Schafer).
Threatened and endangered species—should the goal be protection or stewardship?

According to the International Union for Conservation of Nature (IUCN), there are 22,784 threatened species worldwide (IUCN, 2015), which is a staggering number. Impacts of efforts to conserve special status species have already been quite significant for animal agriculture. For example, one single organization in the United States known as the Center for Biological Diversity (2015) provides information on its website about impacts to animal agriculture.

“Our work protecting endangered species has removed cattle from hundreds of vulnerable riparian areas in national forests in Arizona, New Mexico, and California over the years; in 1999 and 2000 alone, we brought pressure and lawsuits resulting in cows and sheep being removed or restricted on more than 2.5 million acres of habitat for the desert tortoise, southwestern willow flycatcher, and least Bell’s vireo in the vast California Desert Conservation Area.”

“In 2010, Center work helped stop domestic sheep grazing on 7,500 acres in and around the greater Yellowstone ecosystem to protect grizzly bears, lynx, wolves, and bighorn; we also halted grazing on a quarter-million acres of Oregon’s Malheur National Forest to protect steelhead trout. In 2011, Center appeals stopped grazing on 33,000 acres of national forest land in Arizona.”

Again, the quotes above reflect the work of only one organization in one country and over a very short period of time. We did not attempt to find or estimate the total land area removed from animal agriculture to protect endangered species, but we assure you that it is significant and expect it to increase in the future. It is unclear and often debated if removing livestock actually benefits a given threatened or endangered species. Briske et al. (2011) assert that:

“A fundamental premise of effective grazing management is that it supports ecosystem sustainability and restoration of degraded ecosystems.”

Assuming livestock managers are willing to change the way they manage livestock, we predict that the vast majority of conservation efforts for endangered species would not require the removal of domestic livestock. Rather, changing the way domestic livestock grazing is managed can probably address most endangered species conservation needs. However, this approach also assumes that the individuals and groups advocating for endangered species recovery are at least open to the idea that livestock grazing could be compatible with endangered species recovery. Unfortunately, this is not always the case, and too often, endangered species concerns are used opportunistically to forward anti-livestock agendas. Further discussion on this issue is presented by Hendrickson (2015) in this issue of Animal Frontiers. Still, there is hope for collaborative efforts to manage for livestock and endangered species simultaneously as evidenced by projects such as the Ranching and Sonoran Desert Torrtoise Working Group, which produced a document entitled “Best Management Practices for Ranching in Sonoran Desert Tortoise Habitat in Arizona” after 35 yr of self-funded and collaborative efforts.

Environmental litigation is another example of an effect on animal agriculture that is not a land use per se but is a collateral effect of changing land use (from a production-oriented to a protection-oriented paradigm). Environmental litigation is a big business. According to a US Government Accountability Office report (2012) to congress, the number of lawsuits brought under the Endangered Species Act (1973) and the amount paid by the US Treasury Department on behalf of the Department of Interior between March 2001 and September 2010 were 238 and $21,298,971, respectively. Platt (2013) reported that in the US, federal and state governments spent approximately $1.7 billion on conservation of endangered species in fiscal year 2012. A third party evaluation (Holub, 2011) of one Arizona-based environmental groups’ tax reports indicates that:

“Looking at the 2009 IRS Form 990 report it clearly shows on page 9 ‘legal settlement’ income of $1,173,517. The 2008 form 990 shows $1,398,161 in ‘cost recovery for environmental litigation’ at page 9 of that filing. On their 2007 Form 990 at page 8 they list an income source called ‘cost recovery’ of $486,032.”

The livestock industry must continue to work toward good stewardship of natural resources, including threatened or endangered species. As scientists, we suggest that this goal will be better accomplished with science than with litigation.

Effects of energy and or mining on animal production

Recently, Alfred et al. (2015) estimated the impacts of oil and gas development in North America. Those authors estimate that well pads, roads, and storage facilities built in North America from 2000 to 2012 occupy approximately 7.5 (3) million ac (ha) and that the vegetation damaged or lost would be sufficient to feed 5 million mature domestic cattle for 1 mo. Dr. Jay Angerer of Texas A&M [personal communication, and drawing information from Chen et al. (2015) and Fernandez-Gimenez et al. (2015)], who has worked on agriculture and natural resource development projects in Mongolia since 2004, recently indicated that energy/mining is one of the factors having an impact on livestock production in Mongolia. Specifically he stated that:

“I think mining/oil/gas exploration and implementation are causing the biggest land use changes in the central and southern parts of Mongolia. Not only are livestock being displaced by the infrastructure of mining/oil/gas, but the increase in people around these areas looking to work at these facilities decreases the grazeable area, and in turn also increases the need for more livestock products. So, this adds to the degradation of the landscape. In the more mesic areas in the north and
Effects of armed conflict on agriculture and natural resources

Conflict, be it cultural, economic, or military, can have profound effects on land-use and thus, animal agriculture. For instance, armed conflict, poverty, or natural disasters in one country often result in refugees fleeing to surrounding countries. In such cases, pressure on natural resources can be concentrated around international borders and refugee camps. This displacement of humans, and sometimes livestock, often causes depletion of water, forage, fuelwood, and game animals. If energy companies are sloppily and carelessly, there can be significant negative impacts on animal agriculture. On the other hand, when energy companies are knowledgeable and conscientious, animal agriculture will often benefit in the end. Collectively, impacts of energy development are substantial and warrant serious consideration. That being said, there are opportunities for energy development and animal agriculture to be quite compatible (Brunell, 2013; Dote, 2015).

Livestock killed or eaten during conflicts will reduce the number of animals with which to re-engage in animal production for a period of time. Lands once used for livestock production in areas of conflict, deserted by pastoralists, may not return to grazing once the conflict is over and refugees return. There may be such hazards as unexploded ordinance or land mines in place. Water or soil may remain polluted or otherwise physically disturbed by conflict-related activities for long periods of time. Other people may have moved in and occupied lands or water sources and converted these to other agricultural uses. Shifts in traditional gender roles for animal-related occupations may occur if casualties disproportionately affect one gender over another. As alluded to above, animal agriculture may become predominately small ruminant based for widowed heads of households.

Other impacts, positive or negative, may also accrue. In a background note for The World Development Report, Gomez et al. (2010) state:

“The impact of the Daadab camps (in Kenya) on the local host community are widely felt through trading opportunities and reduced food and commodity prices. Furthermore, refugee camps have developed major local markets with considerable purchasing power in relation to pastoral products such as milk and livestock. However, despite these positive indicators, the presence of refugees is also associated with the depletion of firewood and building materials as well as competition for grazing land in the immediate vicinity of the camps. The assessment concludes that impacts on the host community are complex and have both negative and positive aspects.”

Conflict and/or competition for natural resources can be manifest in a variety of shifting land-use patterns and effects. In the Nuba Mountains of Sudan, there has been a long-term interaction between nomadic Arab herders and more sedentary farmers. This relationship has been marked by both cooperation and confrontation, however, in a larger context farming and pastoralism complemented each other. FAO research (Pantuliano, 2005) indicates that during times of cooperation, pastoralists brought their animals from the mountains to graze villagers’ crop stubble after harvest; the fields were fertilized in this manner, and crops were transported to market via the herders’ camels. More recent political conditions have disrupted this arrangement. Resultant changes to land use in this region may be subtle; pastoralists may still reside in the more remote areas and farmers still farm. But the lost connection between these groups and their agro-pastoral coexistence could certainly have long-term effects on both animal and crop production in the region.

Competition for sources of grain and fiber for biofuel production

Ethanol is another example of “good versus evil” depending on one’s perspective and likely, how ethanol effects your paycheck. For instance, a Princeton University-led group (Searchinger et al., 2008) conducted a life-cycle analysis of global biofuel production (primarily ethanol) and concluded that:
“...corn-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse gas emissions over 30 yr and increases greenhouse gases for 167 yr. Biofuels from switchgrass, if grown on US corn lands, increase emissions by 50%...”

In stark contrast are the words from a recent press release by the South Dakota Farmers Union (Sombke, 2015) in response to The Renewable Fuels Standard Reform Act:

“...Our South Dakota farmers and rural communities have benefited greatly from what has been a thriving ethanol industry in our state... Ethanol has become a part of the fabric of many rural communities; if they take ethanol subsidies away, it will hurt schools, jobs, and not to mention the price of corn... The elimination of the corn-based ethanol mandate and blend cap will gut the nation’s biofuel production, strand existing investment in second generation biofuel production, and hurt family farmers, ranchers, and rural communities that have experienced much-needed reinvestment from this policy.”

The effects that changing land use from grazing to corn, soybeans, or other ethanol feedstock have on livestock production are mixed. A direct competitive effect is realized when the acreage available for livestock production is decreased by ethanol production. Although increased biofuel production has led to increased corn costs for livestock, producers of ruminant animals may choose to feed by-products from the ethanol distilling process as a mitigation strategy.

Other feedstocks for biofuel production come from native grasses such as switchgrass, which can produce relatively large amounts of biomass but may not be as productive for ethanol as starchy grains. Sorghum is a crop that could play a significant role in the interaction of biofuel with livestock production. Sorghum is a warm-season grass that can be highly productive and drought tolerant and requires less fertilizer; traits that should be considered attractive for those in either camp of the ethanol debate. Shoemaker and Bransby (2010) have outlined the contribution that various cultivars of sorghum and sorghum hybrids can have in the production of fuel, forage, and grain. The relative contribution of each of these could have profound effects on livestock production in terms of grazeable acres as well as price and availability of feed. Perhaps integrated livestock/grazing/fuel production operations will be a future result?

Pollution of or competition for water used for livestock

Urbanization, in addition to occupying land once used for agriculture, can also have other effects on livestock production. It makes sense that more organisms (human and livestock) consuming a set amount of water will result in competition. Less obvious is that water quality for livestock can also be impacted. Canadian researchers (Hall et al., 1999) who examined fossil records and more recent environmental data on the Qu’Appelle River and Pasqua Lake near Regina, Saskatchewan found that during the late 1900s, 70% of N and P originated from municipal wastes, that taste and odor problems were commonly reported, and that the water quality was insufficient for consumption by humans or livestock. According to Hall et al. (1999):

“Rural population expanded from 1900 to 1930 as Europeans settled available farmland but declined thereafter as a result of drought, war, changing agricultural practices, and increasing urbanization. The cities of Regina and Moose Jaw were established in 1882 but grew slowly until Regina was incorporated as the provincial capital in 1905. The population of Regina increased substantially after 1945, while that of Moose Jaw has remained relatively constant since 1950.”

It should be noted that agriculture was also implicated in this study as a contributor to nutrients in water supplies.

A century of wildfire suppression is one factor contributing to increased fuel loads on public lands in the western US and other countries. During a wildfire, especially along the wildland–urban interface, public attention is deservedly focused on controlling or managing the fire while it is burning. Once the fire is out and the media has gone on to cover another story, those who live and work in the area remain to deal with the consequences. Fire managers have several methods available to them for suppression, depending on such factors as fuel, topography, or weather. Air drops of water and flame retardant are among these. Sometimes the source of water for fire suppression efforts comes from reservoirs intended for livestock. Another consequence, as discussed in the previous paragraph, is that of water quality post-fire. A Colorado State Extension publication informs landowners and managers that:

“Surface water bodies such as ponds and streams are vulnerable to an influx of sediment, ash, fire retardant, nutrients, and other potential contaminants following wildfire. Property owners in burned areas need to protect their ponds and streams from further degradation and evaluate the suitability of these water sources for pets and livestock.”

Livestock operations are often thought of as contributing to nutrient runoff and water contamination, but as described above, they may also be subject to the effects of such events.

Effects of changing land-use or land management that lead to increases in animal agriculture

Slash and burn. If we are going to start an argument with this article, this is probably where it will occur. Slash and burn is a technique as old as agriculture itself. Land is cleared of forest or other vegetation by cutting and burning to make way for cultivation and planting of crops or pasture and to fertilize the soil with ash. Historically, this method was likely sustainable for relatively small and transient human populations, and there would have been a shifting mosaic of patches across the landscape in various stages of use, abandonment, and succession at any given time. In modern times, however, the phrase “slash and burn” is largely identified with deforestation of rain forests in tropical regions such as the Amazon and so understandably carries a negative connotation. We include it here under additive effects to animal agriculture simply in a mathematical sense. Viega et al. (2003) in their report to the World Forestry Congress write:

“Since the 1960s, the cattle herd of the Amazon Basin has increased from 5 million to more than 70–80 million heads. Around 15% of the Amazon forest has been replaced and around 80% of the deforested areas have been covered by pastures (approximately 900,000 km2)... Cattle ranching in the Amazon is often criticized in the scientific literature because of its numerous harmful consequences on economic, social, and ecological grounds (deforestation, land concentration, biodiversity loss, land tenure concentration, and small contribution to regional development). Opposing these viewpoints,
Clearing land that is not currently used for animal or feed crop production will provide for an increase (for some period of time) in these activities. The cost/benefit of these activities will have to be determined by the countries involved and on a case-by-case basis.

Some less controversial would be the release of Conservation Reserve Program (CRP) lands in the US for haying or grazing. The CRP is a 30-yr-old USDA-Farm Service Agency administered program originally designed to reduce erosion on vulnerable lands. In this progeny of the 1950s Soil Bank Program, approximately 25 million ac were enrolled in CRP as of 2014. The maximum acres of CRP were reached in 2007 at approximately 37 million (Widmar, 2014). Program landowners are paid to plant erodible acres to cover crops, typically native grasses. Length of contracts may be 10 to 15 yr, and CRP lands are usually not grazed or hayed, but there are emergency exceptions such as drought. Ethanol is also part of the CRP discussion. Coincident to expiration of the early CRP contracts, high prices resulted in CRP acres removed from the program, grasses plowed under, and fields brought back into corn production. Similar events occurred on switchgrass-occupied acres in the CRP as these fields were converted to harvest for cellulosic ethanol feedstocks. Other more sustainable uses for former CRP lands could be in permanent grazing or haying, perhaps as part of a rotation with long periods of rest. Grassland restoration on current or future CRP lands, managed by fire and grazing, could increase acres available for livestock production.

Similarly, clearing expanding shrub or tree species such as juniper, mesquite, and sagebrush (even though they are native species) is not necessarily a land-use change but is a land-use practice that affects carrying capacity and thus grazing animal production on thousands of acres in the western US. A 1995 review of changes in the distribution of redberry juniper in northwest Texas by Ansley et al. (1995) contains the following:

“Redberry juniper reduces grass productivity, especially on shallow soils, by altering the light environment, soil moisture content, soil nutrient availability, and soil temperature (McPherson and Wright 1990b, Ueckert et al., 1994a). It can increase to the exclusion of nearly all other woody and herbaceous species, thereby reducing biodiversity. Excessive woody cover interferes with movement and handling of livestock, results in inefficient on-site use of precipitation, and diminishes watershed and wildlife habitat values of rangelands (Thurow and Carlson 1994).”

Archer et al. (2011) provide a critical assessment of woody plant management in rangeland conservation efforts. As is often the case in extensive rangeland environments, among these authors’ conclusions is that effective woody plant management depends on a variety of factors including landscape vegetation type, geology and soils, precipitation patterns, and the management goals and objectives. Shrub removal practices are common on grazinglands, but they are not without controversy. Some have argued that efforts to control woody species have been costly and had little overall long-term effect. Past confrontations over juniper treatment erupted between environmental groups who wanted re-growth juniper or other small shrubs to accommodate nesting preferences for black capped vireos and those who wanted old growth mature juniper and other trees species that were more suitable for golden cheeked warblers. Current debate rages over treatment and restoration methods for sagebrush to benefit the sage grouse. As illustrated in the example from southwest Texas, shrub management and grazing practices can be developed to not only benefit domestic livestock but improve wildlife habitat as well.

Far less controversial is the practice of targeted grazing, specifically when applied for fire fuel reduction. Italian authors Lovreglio et al. (2014) refer to grazing (or browsing) specifically by goats, as one of several techniques employed in “preventative silviculture.” They go on to say that although goats were once considered the “razor of the forest,” and over-grazing has been a major environmental problem in the Mediterranean region, properly applied grazing is now considered the most ecologically sound practice for creating fuel discontinuity in that part of the world. The practice of targeted or prescription grazing can fall under the category of land-use change if one considers that it often occurs on the wildland–urban interface (i.e., in areas where housing or business developments are found immediately adjacent to forest or rangelands). These are lands that were probably previously grazed by wild or domestic animals and are also lands that tend to burn. Small ruminants, fairly tractable and typically less scary or obtrusive to urban dwellers than cattle, can be herded in a prescriptive manner to accomplish plant removal objectives in these areas. Other applications of targeted grazing include reduction of invasive species such as leafy spurge, spotted knapweed, or cheatgrass. This practice has even occurred in places as unlikely as Chicago’s O’Hare International Airport on slopes too steep for the safe operation of machinery. While targeted grazing may only provide temporary and transient increases in land area for animal agriculture, it is a niche small business opportunity, especially for beginning livestock entrepreneurs.

Lastly, and related to targeted grazing, smallholder operations in urban areas inspired by the growing popularity of local food movements and the demand for specialty food items such as artisan cheeses may create additional opportunities for animal agriculture. Granted, the total acres
and carrying capacity may be minimal, but the impact for livestock production could be significant in terms of providing entry opportunities for new, non-traditional operators. Imagine the possibilities awaiting agriculture if a generation of young urban professionals and potential entrepreneurs are intimately aware of where their food comes from. Similar opportunities for livestock production on “re-claimed” vacant lots or other unused land could arise from growing and diverse populations in large metro areas, i.e., cultures with a demand for meat and dairy products from small ruminants. Other possibilities for expanding animal production exist as scientists discover ways to exploit the ability of ruminants to use cellulose from a variety of sources such as food or municipal waste.

**Final Words**

One more excerpt in closing:

“Commercial ranchers find it increasingly difficult to maintain production in the western and central regions, which receive low and uncertain rainfall and where there are increases in undesirable woody species. Low profit margins and higher production costs discourage many landowners from maintaining commercial herds.”

Although it may sound that way, the above statement is not about the US. The authors continue by writing that:

“There has been a decline in sheep and wool production from the Nama-karoo region (Dean and MacDonald, 1994), which has been attributed to a decline in resource condition. There appears to be an increase in the number of uninhabited freehold farms in the arid and semiarid regions, suggesting that farms are being abandoned or managed as larger units. Reflecting de-agrarianization trends throughout the developed world, South African rangelands under freehold tenure are becoming depopulated. The children of freehold farmers do not regard farming as an exciting career option, and leave the farm for training in more lucrative career paths.”

We include these statements from Palmer and Ainslie (2005) from their chapter on “Grasslands of South Africa” not to cast a final negative light on our subject but rather to point out that livestock producers worldwide face similar issues. Some issues we in animal agriculture have collectively brought on ourselves and must own up to. Other issues are simply the result of a fast-changing world with a variety of perspectives and views about who we are, what we do, and how we do it. Despite all of the change in the world, the fact remains that those who live here require food, fiber, and a great many by-products from animal agriculture and ecosystem services from the lands that support it. Our hope is that this article has stimulated thought, highlighted possibilities to bring good science to bear on important and challenging problems, and encouraged collaboration by diverse stakeholders to do so.

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About the Authors

Doug Tolleson is an extension rangeland specialist and research scientist for the University of Arizona. He has been located in Camp Verde at the V Bar V Ranch Agriculture Experimentation Station since January 2008. Previous experience includes 9 years as Director of the Grazingland Animal Nutrition Lab at Texas A&M University, 10 years as a Research Associate for Texas A&M in Vernon and Uvalde Texas, and 3 years in a similar position with the University of Arkansas at Booneville. He has worked on cattle and horse ranches in Texas and Arkansas. International experience includes projects to develop range, animal nutrition, and near infrared spectroscopy capacity in Mexico, Mongolia, Mali, India, Ethiopia, Kenya, Uganda, and Tanzania. He is a past President of the Arizona Section, Society for Range Management and is currently the liaison to the Society for Range Management for the American Society of Animal Science. He earned a BS in Animal Science, MS in Reproductive Physiology and a PhD in Rangeland Ecology and Management from Texas A&M University. Correspondence: dr2@email.arizona.edu

Paul Meiman, Associate Professor of Rangeland Ecology and Management has been a member of the Forest and Rangeland Stewardship faculty at Colorado State University since 2006. Prior to that, he worked in a variety of positions in Colorado, Wyoming, Idaho and Oregon. His experience includes positions with the USDA Agricultural Research Service in Idaho, Colorado State University Cooperative Extension (Moffat County Extension Agent) and the University of Wyoming Department of Renewable Resources and Cooperative Extension Service (Statewide Extension Specialist for Rangeland Resources). He has worked extensively with land, livestock and natural resource managers to develop and implement cooperative rangeland monitoring programs and associated resource management and conservation decisions. His interests are closely related to, and have been influenced by on-the-ground interactions with ranchers, land and natural resource managers. Interests include invasive plants, plant/herbivore interactions, livestock grazing management, succession (including post-fire community dynamics), and riparian area management. He earned B.S. and M.S. degrees from the University of Wyoming and a Ph.D. from Colorado State University.