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Animal production and farm size in Holmes County, Ohio, and US agriculture

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Abstract. Animal production in US agriculture during 1997 was compared with Holmes County, Ohio, in which half the farms belonged to the agrarian Amish whose small farms have been successful. To compare the intensity of animal production in regard to land that was already devoted solely to domestic feed, the two systems were scaled so that their average farm sizes contained equal land areas devoted to domestic feed and then their animal production per farm was adjusted by the same scaling. By breeding populations, as well as large imports of feed, feeder pigs, calves, and broiler chicks, Holmes County produced three times more milk, four times the broilers, about the same amount of eggs and cattle, and twice the pigs per scaled farm, and hence per given land area, than in the US. Despite the average farm size in Holmes County having been 40% smaller than in Ohio overall, this production yielded more than twice the energy and protein per scaled farm, or per given land area, compared to the US, and required almost twice the feed and 85% as much grazed pasture forage per farm. This was in accord with the fact that feed consumption in Holmes County was equal to twice its harvested crop production, implying a net feed import equal to its crop production. The latter fact was the main contribution to the productivity of Holmes County in excess of the US and also suggested there would be serious problems in widespread adoption of intensive animal production in regard to agricultural markets, soil fertility, and farm nutrient losses through manure application. Energy conversion efficiency for the five animal products and breeding populations was greater in Holmes County than the US, 10 and 7%, respectively, and likewise for protein, 22 and 13%. Besides imported feed, the higher efficiency of Holmes County was also due to its greater emphasis on milk production, which has benefited from USDA milk price support, modern dairy genetics, and dairy nutrition programs. The lower overall efficiency of the US has been partly a result of the fact that beef production and breeding, judged by feed alone, have been the least efficient of the five animal products in energy conversion and nearly the least for protein, regardless of the fact that among the five products, beef cattle are the only animal that nationally derived much of its nutrition from the large national area of grazing land.

Key words: agricultural productivity, Amish, feed conversion efficiency, protein production

To view the tables, see AJAA18-2_tables.pdf. To view this file you will need Adobe Acrobat Reader which can be downloaded free.

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Introduction

This investigation compares the 1997 level of animal production in two agricultural systems, the US and Holmes County, Ohio. This county was studied because it has a high intensity of animal production per area of farmland despite the fact that its average farm size is small. Half of its farms are conventional, and the other half are small Amish farms, but the total contribution of the latter to Holmes County agriculture is not known (Slates, 2001). The agrarian Amish are a successful example of traditional agriculture with a long history of using less energy-intensive, but productive agricultural practices in a blend of new technologies and old practices (Johnson et al., 1977; Stinner et al., 1989). Holmes County ranked tenth and thirteenth highest among the 88 Ohio counties in gross and net farm income per ha during 1997, respectively (Bender, 2001). Animal products accounted for 92% of the marketed economic value of agricultural products in this county (Bender, 2001). Average farm size was nearly 40 ha for Amish farms (Bender, 2001), contributing to an average of 50 ha for all farms in Holmes County during 1997, much less than the mean of 80 ha for Ohio farms and 200 ha for US farms (USDA, 1999a,b).

This investigation shows that despite small average farm size, Holmes County achieved a much higher intensity of animal production than the nation mainly because of heavy dairy production and large imports of feed, feeder livestock, and broilers through marketing and production contracts. The amount of energy and protein in animal production per area of farmland are compared between the two agricultural systems by means of average farms scaled to the same size of land area. Conversion efficiencies for this energy and protein are then computed from the consumption of feed and pasture forage by the animal production and breeding populations.

Methods

Liveweight production and breeding populations

The five animal products in this study were milk, cattle *(Bos taurus),* pigs *(Sus scrofa),* broilers *(Gallus gallus),* and eggs. They essentially represented the national production of animal products because in 1997 they constituted 96 and 93% of the energy and protein in animal products consumed in our daily diet, respectively (USDA, 2001, p. XIII-5). Breeding populations and the number of animals produced in the US and Holmes County during 1997 were determined from USDA (1999a, 2001).

Total liveweight production in 1997 was reported for the five products in the US by USDA (2001), but only for milk in Holmes County by ODA (1998). Hence, liveweight production of the other four products in the county was calculated, as follows. Since more than half of the cattle sold in Holmes County were dairy calves, total liveweight for cattle was computed from the number sold for calves and older cattle multiplied by the national average liveweights, 160 and 540 kg, respectively (USDA, 1999a, 2001). Likewise, since nearly half of the pigs sold in the county were feeder pigs, total liveweight for pigs was determined from the number sold for feeder pigs and older pigs multiplied by the national average liveweights, 30 kg and 120 kg, respectively (USDA, 1999a, 2001). As a check, application of the respective national average liveweights to the number of calves, older cattle, and pigs slaughtered in the US, adjusted for changes in inventory, gave total liveweights almost exactly equal to the above national totals (USDA, 2001). Thus, this procedure should give accurate production totals for Holmes County.

Total production of broilers in Holmes County was computed from the broilers sold and the national average broiler liveweight of 2.2 kg (USDA, 1999a, 2001). Overall egg production in Holmes County was determined from the county inventory of hens and pullets and the national average production of 255 eggs per hen, 0.059 kg apiece (USDA, 1999a, 2001). Regardless of origin of broilers, egg production in both agricultural systems was reduced for broiler-type eggs produced, the latter calculated as the number of market-weight broilers divided by the national hatch and survival rates of 81% and 93%, respectively, in 1997 (USDA, 2001). Then, the breeding population of hens was apportioned between egg and broiler production according to the number of egg-type and broiler-type eggs produced. Since breeding replacements were negligible in number compared to egg and broiler production (Byerly, 1967), they were not subtracted from production.

Some adjustments were also made to the production totals for cattle and pigs. Liveweight cattle production was already adjusted for a decrease in national inventory by USDA (2001) and did not require adjustment for Holmes County because there was little change in inventory (ODA, 1998; Slates, 2001). National cattle production (i.e., older cattle) was also reduced 3%, which represented the production on public grazing lands that were not included in the land area counted in this study (Committee on Government Operations, 1986). It was not necessary to offset pig production in Holmes County for breeding replacement because there was little purchase of sows from outside the county due to the fact that most pig production was on Amish farms that raised their own sows (i.e., boars were negligible). About one-fifth of the feeder pigs sold by farms in Holmes County remained in the county (Slates, 2001) and thus were subtracted from the total sold to avoid double counting with respect to production leaving the county. This correction was the only undocumented verbal information in the calculations for this study and amounted to less than 1% of the energy and protein produced by the five animal products in Holmes County during 1997.

Land area

To compare the production per unit area of farmland, the average farm in the US was scaled down by a factor of 1.43 (i.e., 50ha÷35ha) to give the same cropland-equivalent area per farm devoted to domestic feed as in Holmes County (i.e., 35ha), and the average animal production per US farm was then scaled down by this same factor (Table 1). The land area for average farm size was not total farmland but only land applicable to animal production, namely private pasture and cropland devoted solely to domestic feed consumed in the US or Holmes County, as opposed to exported feed or crops. Public grazing lands were not included because nationally they accounted for 37% of grazing land area (USDA, 1996, 1999b), but only 3% of beef production (Committee on Government Operations, 1986), which would have disproportionately decreased the production per unit area of farmland. Since average pasture in the US is unproductive compared to cropland (current national average yield is seven times greater on cropland than pasture, Table 1) and would thus decrease the production per unit area of farmland, average farm size in both agricultural systems was based on cropland-equivalent area. In this measure, pasture area was reduced to equivalent cropland area on the basis of relative average yields and then summed with cropland. The resulting cropland-equivalent areas for Holmes County and the US were 35 and 50 ha per farm, respectively (Table 1). The respective areas were 70 and 25% of the mean farm sizes in Holmes County and the US reported by USDA (1999a,b).

Energy and protein conversion efficiencies

Liveweight production totals were converted to energy and protein on the basis of liveweight composition (Table 2). Next, annual consumption of feed and pasture forage was computed by applying feed consumption factors to liveweight production totals and breeding populations (Table 3). USDA reported feed consumption factors in CFU, or corn?equivalent feed units (*Zea mays* L.). This unit of measure indicated the substitution value of a feed for corn at 13.5% moisture, as determined in numerous feeding trials with different kinds of livestock in various regions of the US. Feed consumption factors have historically included grazed pasture forage (Jennings, 1958), and that is still the case nowadays because USDA has been deriving its feed consumption factors by an indexing procedure based on 1969-1971 animal weighting factors (Baker, 1998). The 1969-1971 factors were based on loss-adjusted minimum feed requirements in which the roughage clearly included pasture forage (Allen et al., 1974). Hence, the feed consumption factors for 1997 in this present investigation are based on feed and pasture forage. This was also confirmed by examination of feed consumption factors for each year since 1909, which show no abrupt, persistent decrease that would suggest permanent omission of pasture forage from some year onwards (Jennings, 1958; USDA, 1972, 1985, 1996, 2001).

Feed consumption factors were determined for maintenance and replacement of breeding populations (Table 3). It was not necessary to calculate the consumption required for maintenance of dairy cows and egg-laying hens because it was already in the feed consumption factors for milk and egg production resulting from the consumption by cows and hens. Since culled dairy cows were part of liveweight cattle production, their replacement was not charged to milk production. Instead, application of the feed consumption factor to liveweight cattle production retroactively imputed previous consumption by culled dairy cows to cattle production (Byerly, 1975). The portion of the breeding population replaced annually was the inverse of the following values for productive life (years): dairy cows, 3; beef cows, 5; sows, 3; and hens, 1 (USDA, 2001).

Another consideration for consumption was that Holmes County imported a large number of feeder pigs, calves, and broiler chicks for which the eventually finished liveweights included the imported weights. Hence, to impute consumption for the imported weights, the number of imported calves and feeder pigs were determined from USDA (1999a), which were multiplied by national average liveweights of 160 and 30 kg, respectively, and then by feed consumption factors (USDA, 2001). Regardless of origin of broiler eggs, feed for broiler production included feed for egg production based on the above egg and broiler weights and hatch and survival rates.

Consumption was also partitioned between feed and pasture forage because four of the five products were produced from little or no pasture forage compared to beef cattle. This allowed comparison of beef cattle with the other products on the basis of feed alone. Feed and pasture forage constituted 40 and 60%, respectively, of the national diet in CFU for beef cattle, and 90 and 10% for dairy cattle (Lin et al., 1990; Byerly, 1975). It was assumed that these proportions also applied to Holmes County. Since the national diet for pigs and chickens was almost entirely feed (Lin et al., 1990), total consumption of feed was the sum of beef and dairy feed plus the overall consumption by pigs, eggs, and broilers. Hence, consumption of pasture forage was determined only from beef and dairy cattle.

The annual consumption of feed and pasture forage in CFU was converted into energy and protein on the basis of US grade 2 dent corn with an oven-dry content of 10.6% protein and 18.4 MJ kg^{-1} (2,000 kcal lb^{-1}), both then adjusted for 13.5% moisture content (Crampton and Harris, 1969, Ref. No. 4-02-

915). Finally, conversion efficiencies were calculated as ratios of energy or protein between the animal production and the consumption of feed and pasture forage, and in the case of cattle, feed alone was also considered.

Results

Liveweight production and breeding populations

With the average US farm scaled to contain the same cropland-equivalent area devoted to domestic feed as in Holmes County, the average dairy cow herd per farm was four times larger in Holmes County than the US, but produced only three times more milk (Tables 4 and 5). This relative milk production was smaller than the relative dairy herd size mostly because Amish farmers in Holmes County preferred to market high-butterfat milk from Jersey and Guernsey cows even though milk volume per cow was less compared to other dairy breeds.

In reverse of the situation for dairy cow herds, the average beef cow herd was nearly four times larger in the US than in Holmes County, but liveweight production of older cattle per farm was only 1.5 times greater (Tables 4 and 5). This relative production was less than the ratio of 1.9 expected from the dairy and beef breeding populations (Table 4) in terms of beef yearlings and culled beef and dairy cows, given the average productive life of 3 and 5 years for dairy and beef cows, respectively (USDA, 2001). This relative production was less than expected because Holmes County imported a large number of calves, many of which were finished as older cattle.

Total liveweight production of calves and older cattle per farm was roughly the same between the two agricultural systems for two reasons (Table 5). One is that the total herd of beef and dairy cows per farm was nearly equal between the systems (Table 4), resulting in about the same number of weaned calves, but not equivalent production from these calves. The other reason was that the greater emphasis on yearling production from weaned calves in the US was somewhat balanced in Holmes County by the large import of feed and calves and by the quicker turnover time in productive life of dairy cows compared to beef cows, resulting in more culled cows from the much larger dairy cow herd per farm in the county.

Total liveweight pig production per farm, and hence per unit area of cropland-equivalent, was about twice as great in Holmes County as in the scaled US system (Table 5). This ratio was also true for the number of sows per farm (Table 4).

Although egg production was reduced 31% in Holmes County for eggs devoted to broiler production, and only 13% in the US, egg production per scaled farm was 1.2 times greater for the former compared to the latter (Tables 4 and 5). Liveweight broiler production per scaled farm was also nearly four times greater in Holmes County than the US, partly because 90% of the broiler production in the county was contract production by Amish farmers as an add-on practice to their dairy farming (Slates, 2001). The relative size between the two agricultural systems for egg-type hen flock per farm was the same as the relative egg production, and likewise for broiler-type hen flock and broiler production, only because the overall hen flock was apportioned according to the relative production of egg-type and broiler-type eggs (Methods section).

Imported animals

The number of all sold cattle per farm in Holmes County, 17.9, minus the number of weaned calves from the dairy and beef cows, 13.2 (i.e., 14.7x0.90, number of cows and national calving rate), yielded 4.7 imported calves per farm (Table 4, assumed little change in inventory). The number of all pigs sold per farm in Holmes County, 79, minus the number of weaned pigs from the sows, 70 (i.e., 4.0x8.7x2, number of sows, average litter size, and number of farrowings per sow), yielded 9 imported feeder pigs per farm (Table 4, assumed little change in inventory). These imported animals represented an imported liveweight per farm of 750 kg in calves and 270 kg in feeder pigs, for which consumption of feed and pasture forage was imputed to Holmes County.

Energy and protein in production and consumption

Between the two agricultural systems, milk followed by broilers in Holmes County resulted in the most energy and protein per farm, and pigs almost tied with broilers in energy (Table 6). Within Holmes County on a per-farm basis and consequently in reality at the county level, milk yielded 45% of the energy and protein in the five products. But, milk production and breeding population together accounted for less than 25 and 10% of the consumption of feed and pasture forage, respectively, in the county (Tables 7 and 8). Per farm, and hence per unit area of cropland-equivalent, the milk in Holmes County contained more protein and almost as much energy as the five products combined for the US, but its production and breeding population required only 40% as much feed as the five US products and less than 10% as much pasture forage. Broilers in Holmes County yielded more protein per farm than milk, cattle, and broilers together in the US, albeit the broiler production and breeding population needed only three-fourths as much feed per farm as the three US products.

Within the US on a per-farm basis and consequently in reality at the national level, milk supplied at least one-third of the energy and protein in the five products, but its production and breeding population required less than 15% of the feed consumption and only a few percent of the pasture forage (Tables 6 and 8). At the farm and national levels, the production of cattle in the US resulted in as much energy as pigs and almost as much protein as broilers, although its production and breeding needed nearly twice the feed for pigs or more than three times the feed for broilers, as well as almost all of the national pasture forage consumed. Again at both levels, cattle yielded one-fourth of the energy and protein in the five US products, but its production and breeding required nearly 45% of the feed consumption and almost all of the consumed pasture forage.

We could say that Holmes County produced about the same amount of energy (or protein) per farm as the US in cattle and eggs, twice in pigs, three times in milk, and four times in broilers (Table 6). However, these ratios are merely a reiteration of the above ratios for liveweight production because each energy or protein content (Table 2) was applied to the liveweight production in both agricultural systems (Table 5), thus canceling out in the ratios. The energy and protein contents did not cancel out in the ratios for the five animal products combined, with Holmes County having produced 2.2 times more energy per farm and 2.5 times more protein than the US (Table 6). This production, including breeding populations, required 1.9 times as much feed per farm as in the US, but only 85% as much pasture forage (Table 8).

Compared to the US, the greater production of protein and energy per farm in Holmes County was achieved with less feed and pasture forage per farm for the breeding populations on an absolute basis and also relative to the consumption for animal production (Table 7). These facts were also true for feed alone.

Consumption by breeding populations relative to consumption for animal production was about the same between the US and Holmes County for pigs, eggs, and broilers (Table 7). In Holmes County, it was relatively greater for milk and lower for cattle compared to the US. In the former case, the breeding population represented a greater relative demand in Holmes County because its prevalent Jersey and Guernsey breeds yielded less milk volume per cow than in the US. In the latter case, the beef cow herd represented a smaller relative demand in Holmes County because a significant amount of cattle production in the county resulted from culled dairy cows and imported calves. **Energy and protein conversion efficiencies**

The efficiencies for conversion of feed and pasture forage (Table 9) were in fair agreement with values reported by Bondi (1982) and Ensminger (1991) and did not exceed feasible efficiencies (Byerly, 1967; Balch and Reid, 1976). For production alone in milk, eggs, and broilers, the efficiencies were mathematically the same between US and Holmes County because consumption was calculated on the basis of liveweight production, thus permitting the latter to cancel out of the conversion ratio. In other words, efficiency was determined by energy or protein content (Table 2) and feed consumption factor (Table 3). For cattle and pigs, the efficiencies were different between the US and Holmes County because feed consumption in Holmes County applied to imported animals as well as production (Methods section).

Among the five animal products for production alone, milk had the highest efficiencies for conversion of feed and pasture forage into energy and protein, 23 and 50%, respectively, followed by broilers with 38% for protein, but only 11% for energy (Table 9). Cattle in the US and Holmes County had the lowest efficiency for energy, 3-4%, and protein, 6-7%. Even on the basis of feed alone, cattle production, including that from pasture forage, was lowest in energy efficiency, 9-10%, and second lowest in protein, 15-17%.

Energy efficiency for production of the five products in the US and Holmes County was 9 and 11%, respectively, and protein efficiency, 17 and 23% (Table 9). With breeding populations, the respective efficiencies for energy were 7 and 10%, and protein, 13 and 22%. With inclusion of breeding populations, the relative decrease in conversion efficiencies was less for pigs, eggs, and broilers compared to milk and cattle (Table 9). Cows have a large feed cost for maintenance and replacement, the latter in which the two years to raise heifers for replacement are proportionally not much smaller than the productive life of 3-5 years for cows. The inclusion of beef cows in Holmes County produced only a small relative decrease in conversion efficiencies as a result of no beef breeding population imputed for the imported calves or culled dairy cows (Table 9).

Discussion

Farm size and productivity

Scaling of farm size allowed comparison of the US and Holmes County over equal areas of cropland-equivalent devoted to animal production, i.e., 35 ha per farm. Animal production could have been calculated on a per-hectare basis, but this potentially could have been confused with per-hectare productivity in other studies. The latter unit hectare was land devoted to a particular animal or crop, but our unit hectare would have been apportioned among all animals and domestic feed crops on the average farm.

The US was favored by our use of cropland-equivalent area for scaling farm size because it resulted in a greater reduction of land area assigned per farm in the US than Holmes County, thus leading to a larger increase in production per given area for the US. The larger reduction in land area for the US was due to the greater proportion of pasture in the US than Holmes County (i.e., 74 and 33%, respectively, Table 1) and the greater reduction of unit pasture area into cropland-equivalent area in the US than Holmes County (i.e., respective multiplication factors of 0.14 and 0.70 from the ratio of pasture yield to crop yield, Table 1). If the direct sum of pasture and cropland area had been employed instead of cropland-equivalent area, then the mean area per farm would have been 140 and 39 ha in the US and Holmes County, respectively (Table 1). This would have given a scaling factor of 3.6 (i.e., 140÷39) instead of our factor of 1.43, thus resulting in US production values per scaled farm (Tables 4, 5, and 6) that would have been 2.5 times smaller than in this study (i.e., 3.6÷1.43). Moreover, the US was favored by our omission of the large national area of relatively unproductive public grazing land in the calculation of average farm size, including omission of its minor beef production in national cattle production (Methods section).

Compared to the US, the analysis showed that Holmes County produced 2.2 times more energy per scaled farm and hence per given area, and 2.5 times more protein. This production required 1.9 times as much feed per farm and 90% as much pasture forage. The ratio of 1.9 is in expected agreement with independent calculations that feed requirements in Holmes County were 2.0 times its harvested crop production in 1997, the latter implying that the county had a net import of feed equal to its crop production (Bender, 2001). From these numbers, if Holmes County were to reduce its feed requirements by half (i.e., have no net import of feed), then compared to the US per farm, its feed requirements would be about the same and its energy and protein production would roughly be little greater. This suggests that the primary reason for the greater productivity in Holmes County was the large import of feed, which enabled the county to employ larger breeding populations per farm and to import substantial numbers of feeder pigs, calves, and broiler chicks. Agreement was expected between the above ratios of 1.9 and 2.0 because both ratios effectively compare feed requirements to feed production from cropland devoted solely to domestic feed.

The average farm size in Holmes County was 50 ha, only 60% of the mean size of 80 ha in Ohio (USDA, 1999a). Despite small farm size in Holmes County, the analysis found that its energy and protein production per scaled farm, and hence per given area, was more than twice as much compared to the US (i.e., scaled farms had the same cropland-equivalent areas). This result concurs with the observation by Rosset (1999) that the total output of crops and animals per unit area is greater for small farms than large ones in various industrial and developing countries. For example, across the US in 1992, farms with median size of 11 and 23 ha, respectively, had about four and two times the average gross dollar output per ha that was similar for consecutive categories within a range of 80-280 ha in median farm size (Rosset, 1999). The two respective size categories had 2.5 and 1.5 times the average net dollar output per ha that was again similar for the larger consecutive size categories. In addition, Tomich et al. (1995) have noted that there is much evidence in developing countries for a decline in total factor productivity per unit area as farm size increases, the well-known "inverse relationship" between farm size and output. All these findings are partially explained by the observation that it would be easier for a farmer to achieve a higher density of farm inputs per ha and thus higher productivity on a small farm than a large one simply because the total farm inputs that the farmer could feasibly control during the year would be spread over a smaller land area, as exemplified by small farms in Holmes County.

Energy and protein conversion efficiencies

Energy and protein efficiencies for the five products and breeding populations combined were greater in Holmes County than the US (Table 9). One reason for the higher overall efficiency in Holmes County was that its beef and pig breeding populations were smaller relative to production than in the US as a result of imported calves and feeder pigs in the county and more culled dairy cows per farm credited to cattle production.

Another reason for the higher overall efficiency in Holmes County was that, compared to the US, energy and protein production per farm in Holmes County was proportionally derived more from milk and broilers and less from cattle (Table 6). With breeding populations in the US or Holmes County, milk was three times and broilers about twice as efficient in energy and protein as cattle judged by feed alone (Table 9). In other words, the higher overall efficiency in Holmes County have been largely a result of its milk production benefiting from USDA milk price support, modern dairy genetics, and dairy nutrition programs.

In contrast to Holmes County, the lower efficiency in the US has been partly due to the utilization of the large national area of grazing land by beef cattle, the only animal among the five products that can derive much of its nutrition on grazing land far away from the farmstead (Methods section). However, beef production has been accompanied by greater than adequate consumption of feed driven more by price and government policy than by nutritional necessity for cattle or people (NRC, 1989). Hence, the lower overall efficiency in the US has been due not solely to utilization of grazing land, but also to the fact that beef production and breeding, judged by feed alone, have been the least efficient of the five animal products in energy conversion and nearly the least for protein (Table 9).

Implications

The US would not be able to emulate the intensity of animal production in Holmes County because national and global agricultural markets would be disrupted by our increased export of animal products and our substantial import of feed. This feed import by the US would create an undesirable dependency on other nations for feed, analogous to our national petroleum imports or the large food imports by poor Third World countries.

The intense production of animals in Holmes County is symptomatic of large ratios of expenses to gross income in US agriculture that force small farms to produce large amounts of animal products in order to make adequate net incomes (Bender, 2001). Farmers in Holmes County have maintained a low level of farm inputs and have spread their costs by making diverse use of buildings, labor, and other inputs (Stinner et al., 1989). They have also operated a variety of enterprises on their farms to receive more income through value-added products. The federal government could increase farm income through price supports and other policy.

The soils in Holmes County benefit from a level of nutrients through imported animal feed that could not be attained by a majority of the counties in the US. The feed requirements in Holmes County were twice the harvested crop production of the county, implying a net feed import equal to the harvested crops (Bender, 2001). As a consequence, soil productivity in the county has benefited from a net import of nutrients roughly equal to the nutrients in the total crop harvest, the latter already being returned as manure to cropland with some losses. Hence, there may likely be local environmental problems such as soil buildup, runoff, and leaching of nitrogen and phosphorus associated with application of large volumes of manure from imported feed to small areas of cropland (NRC, 1993). It would be physically impossible for a majority of the counties in the US to achieve a relative net import of this size, unless feed was imported from other nations. For example, in 1997 only one-fourth of the counties in Ohio had a net import of feed, none approaching the relative magnitude of Holmes County, and the other three-fourths, a net export (Bender, 2001). Thus, national adoption of organic farming practices will not result in soils as fertile as Holmes County unless other farming practices are employed besides return of animal manure to cropland.

Conclusions

Despite its average farm size being 40% smaller than in Ohio overall, Holmes County produced in 1997 more than twice the energy and protein per scaled farm, and hence per given area, than the US. This reflected the general pattern noted by Rosset (1999) and Tomich et al. (1995) that small farms have greater total output of crops and animals per given land area than large farms. Moreover, energy conversion efficiency for the five animal products and breeding populations was greater in Holmes County than the US, 10 and 7%, respectively, and likewise for protein, 22 and 13%. The greater production and efficiency in Holmes County have been a result of its exceptionally large import of feed and feeder animals and also its efficient milk production benefiting from USDA milk price support, modern dairy genetics, and dairy nutrition programs.

The lower conversion efficiency in the US has been partly due to the utilization of the large national area of grazing land by beef cattle accompanied by more than adequate consumption of feed such that, judged by feed alone, beef production and breeding have been the least efficient of the five animal products in energy conversion and nearly the least for protein. The excessive consumption of feed by beef cattle has been driven mostly by prices and government policy and should be reduced to levels sufficient for cattle and human nutrition.

Holmes County has been distinguished by successful, small-scale farming. Its farmers have retained various traditional practices, but they have also adopted some modern technologies and practices that can be profitable on small farms. Hence, these small farms are not completely self-contained and independent from US agriculture. In return, some farming practices in Holmes County have proven to be productive and less energy-intensive and should be incorporated into conventional American farming.

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References

1. Allen, G.C., E.F. Hodges, and M. Devers. 1974. Livestock-Feed Relationships: National and State. USDA Statistical Bulletin 530. U.S. Dept. of Agriculture, Economic Research Service, Washington, DC.

2. Baker, A.J. 1998. Estimating feed use: Background and issues. USDA Feed Yearbook. FDS-1998. U.S. Dept. of Agriculture, Economic Research Service, Washington, DC. Web site http://usda.mannlib.cornell.edu/reports/erssor/field/fds-bby (viewed 22 October 2001).

3. Balch, C.C., and J.T. Reid. 1976. The efficiency of conversion of feed energy and protein into animal products. In A.N. Duckham, J.G.W. Jones, and E.H. Roberts (eds.). Food Production and Consumption: The Efficiency of Human Food Chains and Nutrient Cycles. North-Holland Publishing Co., Amsterdam. p. 171-198.

4. Bender, M.H. 2001. An economic comparison of traditional and conventional agricultural systems at a county level. Amer. J. of Alternative Agric. 16:2-15.

5. Bondi, A. 1982. Nutrition and animal productivity. In M. Rechcigl (ed.). CRC Handbook of Agricultural Productivity. Vol. II, Animal Productivity. CRC Press, Boca Raton, Florida. p. 195-212.

6. Byerly, T.C. 1967. Efficiency of feed conversion. Science 157:890-895.

7. Byerly, T.C. 1975. Feed use in beef production: A review. J. of Animal Sci. 41:921-932.

8. Byerly, T.C. 1982. Agricultural productivity: Potential and constraints. In M. Rechcigl (ed.). CRC Handbook of Agricultural Productivity. Vol. II, Animal Productivity. CRC Press, Boca Raton, Florida. p. 265-304.

9. Committee on Government Operations. 1986. Federal Grazing Program: All is Not Well on the Range. US Congress, House of Representatives, Washington, DC.

10. Crampton, E.W., and L.E. Harris. 1969. Applied Animal Nutrition: The Use of Feedstuffs in the Formulation of Livestock Rations. 2nd ed. W.H. Freeman and Co., San Francisco.

11. Ensminger, M.E. 1991. Animal Science. 9th ed. Interstate Publishers, Danville, IL.

12. Jennings, R.D. 1958. Consumption of Feed by Livestock, 1909-1956: Relation between Feed, Livestock, and Food at the National Level. USDA Production Research Report 21. U.S. Dept. of Agriculture, Washington, DC.

13. Johnson, W.A., V. Stoltzfus, and P. Craumer. 1977. Energy conservation in Amish agriculture. Science 198:373-378.

14. Lin, W., G. Allen, and M. Ash. 1990. Livestock feeds. In J.R. Barse (ed.). Seven Farm Input Industries. Agricultural Economic Report 635. US Dept. of Agriculture, Economic Research Service, Washington, DC. p. 66-78.

15. NRC. 1989. Alternative Agriculture. National Research Council. National Academy Press, Washington, DC.

16. NRC. 1993. Soil and Water Quality: An Agenda for Agriculture. National Research Council. National Academy Press, Washington, DC.

17. ODA. 1998. Annual Agricultural Report. Ohio Dept. of Agriculture, Ohio Agricultural Statistics Service, Reynoldsburg, Ohio. Web site http://www.nass.usda.gov/oh/oh.htm (viewed 29 July 2002).

18. Rosset, P.M. 1999. The multiple functions and benefits of small farm agriculture in the context of global trade negotiations. Policy Brief 4. Institute for Food and Development Policy, Oakland, CA. Web site http://www.foodfirst.org (viewed 28 May 2001).

19. Slates, Dean. 2001. Personal communication, Ohio State University Extension Service, Millersburg, Ohio, 10 September 2001.

20. Stinner, D.H., M.G. Paoletti, and B.R. Stinner. 1989. In search of traditional farm wisdom for a more sustainable agriculture: A study of Amish farming and society. Agric., Ecosyst., and Environ. 27:77-90.

21. Tomich, T.P., P. Kilby, and B.F. Johnston. 1995. Transforming Agrarian Economies: Opportunities Seized, Opportunities Missed. Cornell University Press, Ithaca, NY.

22. USDA. 1972, 1985, 1996. Agricultural Statistics. US Dept. of Agriculture, Economic Research Service, National Agricultural Statistics Service, Washington, DC.

23. USDA. 1996. Major Land Uses (1945-1992). US Dept. of Agriculture, Economic Research Service, Washington, DC. Web site http://usda.mannlib.cornell.edu/data-sets/land/89003 (viewed 24 August 2001).

24. USDA. 1999a. 1997 Census of Agriculture. Vol. 1, Geographic Area Series. Part 35, Ohio State and County Data. Chpt. 2, County-Level Data. US Dept. of Agriculture, Economic Research Service, National Agricultural Statistics Service, Washington, DC. Web site http://www.nass.usda.gov/census (viewed 22 February 1999).

25. USDA. 1999b. 1997 Census of Agriculture. Vol. 1, Geographic Area Series. Part 51, United States Summary and State Data. Chpt. 2, State-Level Data. US Dept. of Agriculture, Economic Research Service, National Agricultural Statistics Service, Washington, DC. Web site http://www.nass.usda.gov/census (viewed 10 August 2001).

26. USDA. 2001. Agricultural Statistics. US Dept. of Agriculture, Economic Research Service, National Agricultural Statistics Service, Washington, DC. Web site http://www.usda.gov/nass/pubs/agr01/acro01.htm (viewed 6 August 2001).

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