Indian Journal of Animal Sciences 75 (10): 1233–1237, October 2005

Review on raising livestock productivity in crop-livestock systems in India: challenges and implications for research

P PARTHASARATHY RAO[1] and P S BIRTHAL[2]

ICRISAT, Patancheru, Andhra Pradesh and NCAP, Pusa, New Delhi 110 012 India

Key words: Crop-livestock systems, Demand, Multivariate analysis, Productivity

The world's livestock production systems are divided into 3 broad categories, based on the degree of integration with crops and land — grazing systems, mixed crop-livestock farming systems (MCLS) and industrial systems or landless systems (Sere and Stienfield 1996). Historically, at low population densities and land abundant scenario, crop and animal production are extensive/specialized and hence, crop-livestock interaction is weak. However, as population density increases, there is increasing pressure on cropland, with fallow and pastureland increasingly brought under cultivation. This, in turn, raises farmers' dependence on crop-residues, demand for manure and animal traction. There is thus a move towards crop-livestock interaction, where crops and animals are integrated on the same farms (McIntire *et al.* 1992).

Livestock kept in MCLS are primarily large and small ruminants that can convert highly fibrous material and grasses with little or no alternative use into valuable products (FAO 2000). Being partially closed systems, MCLS are environmentally the most desirable systems. The waste products of one enterprise (crop production) can be used by another enterprise (animal production), which in turn returns its own waste (manure) back to the first enterprise (Thomas and Zerbini 1999). de Haan *et al.* 1997 stated that because it provides many opportunities for recycling and organic farming and for a varied, more alternative landscape, mixed farming is the favorite system of many agriculturists and environmentalists. In recent years, intensification of mixed systems and unfavorable government policies (subsides on fertilizers, diesel etc) has led to a weakening of crop-livestock interactions that has implications for the environment and sustainability of the system.

Crop-livestock systems: India

In India too, small-scale mixed crop-livestock farming is the common, and indeed the dominant form of production system. For many centuries, the use of bovines (mainly bullocks) for cultivation (especially for land preparation) has been nearly universal in the region. Farmers maintained non-working animals as a source of calves, milk and manure. Most milk animals (cows and buffaloes) are found in rural areas and owned by cultivators. Crop residues and byproducts are the major source of feed. The bulk of milk is produced in rural areas, which meet the bulk of milk needs of urban population (Vaidyanathan 1998).

Integrating crops and livestock on the same farms helps in diversifying the sources of income and employment for the resource-poor farmers. The market for livestock products offers an opportunity for augmenting their income, even for those who do not have access to land and capital resources (FAO 2000). Additionally, for the resource poor livestock is a living savings account with offspring as interest. Being liquid compared with land, it acts as a cushion against risk and uncertainty in crop production. By providing food (milk, meat and eggs), livestock makes immense contributions to food security. It is an important source of industrial raw material, such as hide, skin, bones, blood, etc. Its banking and insurance functions at the household level are well recognized. Development of livestock sector promotes gender equity since women play an important role in the care and maintenance of animals (Rangnekar 1995, 1998, Devendra *et al.* 2000, Birthal and Parthasarathy Rao 2002).

Diversity and evolution of systems

A major feature of MCLS is the great diversity and complexity in the crops grown, and livestock species raised. Annual and perennial crops, tree species, ruminants and non-ruminants are all integrated on the same farm. Secondly, the systems are in different stages of evolution, in terms of commercialization (degree of integration with markets), species reared and adoption of available technologies. Grazing, tethering, stall-feeding, cut and carry for stall-feeding are all practiced in varying degrees.

Over the last few decades, India has made tremendous progress in food grain production through intensive use of high-yielding seeds, fertilizers and mechanical draught power. Concurrently, the banking and insurance institutions

Present address: [1]Present address: Senior Scientist, ICRISAT, Patancheru, Andhra Pradesh 502 324.

[2]National Fellow, National Center for Agricultural Economics and Policy Research (NCAP), Pusa, New Delhi 110 012.

too have been developed to support technological efforts. Thus in the green revolution belt/irrigated agriculture the non-food functions of livestock have diminished. Some examples include, decline in draught power due to mechanization of agriculture operations and transportation, use of organic fertilizers in place of manure, faster growth in dairy buffalo population, ovine and monogastric population.

Agro-climatic (rainfall, LGP), technological (irrigation, improved cultivars and modern inputs, crossbred animals, animal nutrition), socioeconomic factors (land holding size, population density, access to credit) and infrastructure availability like roads, markets etc., drive these changes. In recent years, demand side factors such as income growth, urbanization and change in tastes and preferences is driving the demand for livestock products and have become an important cause for changes in crop-livestock systems. Paroda and Kumar (2000) found that the income elasticity of demand for livestock products is higher compared to cereals, pulses and oilseeds, implying faster growth in demand for livestock products as incomes rise. Owing to structural changes in the economy urbanization is growing at more than 3% per annum leading to change in dietary patterns in favour of high value commodities including livestock products. Parthasarathy Rao and Birthal (2004) estimated that the demand for milk in India will rise to 112 million tonnes in 2010, and more than double to 155 million tonnes in 2020 from the current level of 74.5 million tonnes. Meat demand will be more than double from the current levels to 9.56 million tonnes in 2020. The demand for non-ruminant meat (poultry meat and pork) will increase faster than that for ruminant meat.

One implication of the growth in demand is the emergence of commercial milk and meat production in urban and peri-urban centers that are closer to the demand centers. These specialized systems depend on outside supply of feed and other inputs and are thus environmentally least desirable. Secondly, commercial livestock production is based on very few breeds that have been selected for intensive production. Turnover and the movement of better breeds to the city and their subsequent slaughter after lactation, leads to loss of valuable genetic material, threatening domestic animal diversity. There is a need to internalize the environmental costs, and stricter controls on pollution due to waste products from these systems.

The recent growth in peri-urban dairying and specialized systems, though growing fast, are still not widespread and will be able to meet only localized demand for livestock products. MCLS will continue to play a key role in animal production in the near-to foreseeable future. Most of the future demand for livestock products will have to be met from millions of small-holders in these systems. The challenge for the future is to realize the potential offered by crop-livestock systems by raising their productivity through the introduction of appropriate technologies and at the same time create conditions for positive crop-livestock interactions, for long run sustainability of these systems while protecting the environment.

Livestock productivity in mixed systems

During the last two decades the mixed crop-livestock systems in India have responded to the growing demand for livestock products as reflected in the impressive growth in the livestock outputs like milk and meat. The growth however, was largely achieved by an increase in animal numbers, with minimal contribution through productivity gains Tables 1 and 2). Only for milk productivity growth contributed around 40% to milk output growth.

Table 1. Livestock population and growth: India, 2000

Species	Population (million nos.)	Share in South Asia (%)	Growth 1980–2000 % per annum
Cattle	214.9	79.6	0.6
Buffalo	92.0	77.3	1.7
Sheep	58.0	69.0	1.3
Goat	122.1	58.4	1.5
Pig	16.0	94.3	3.1
Poultry	386.8	53.8	3.3

Source: FAOSTAT, FAO.

Table 2. Production and growth of livestock outputs: India, 2000

Commodity	Production ('000 t)	Growth in production 1980–2000 (%/annum)	Yield (kg/animal/ annum)	Growth in yield 1980–2000 (%/annum)
Milk				
Cow	32,733	4.7	936.0	2.8
Buffalo	42,883	4.9	1411.0	1.9
Sheep	-	-	-	-
Goat	3,120	5.1	138.0	2.0
Total	78,737	4.8	-	-
Meat and eggs				
Beef	1,421	2.8	103.0	0.7
Buffalo	1,404	2.0	138.0	0.0
Mutton and lamb	228	1.4	12.0	0.0
Goat	465	2.4	10.0	0.0
Pork	560	3.9	35.0	0.0
Poultry	558	7.9	0.9	0.0
Total meat	4,773	2.9	-	-
Hen eggs	1,725	6.0	11.9	2.0

Source: FAOSTAT, FAO, 2002.

A closer examination revealed that there is a big gap between yields obtained on the farm and potential yields obtained on research farms. For example, mean annual yield of indigenous cattle is about 618 kg, while the lactation yield on research farms for some of the important milch breeds varies from 1 137 to 1 931 kg. Similarly, average milk yield of crossbred cows is 2 127 kg, as against the obtainable yield range of 2 326–3 196 kg. For buffalo, it is 1 333 kg, while the obtainable yield goes up to 1 855 kg (Birthal 2002).

Not only livestock productivity levels in these systems continue to be abysmally low, their productivity growth rates have decelerated in the nineties compared to eighties threatening the competitiveness of these systems and consequently the very survival of small-scale mixed crop-livestock farmers. In the next section we will look at the factors influencing livestock productivity and the reasons for low productivity to better target research and policy initiatives.

Determinants of livestock productivity

Livestock productivity will depend on agro-ecological factors such as rainfall, irrigation, adoption of improved technologies; socio-economic factors such as land holding size, population density, and infrastructure availability. We hypothesize that feed availability is an important factor determining productivity.

To determine the factors influencing livestock productivity we have used the '*district-level database for India*', available with International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) from 1980 to 1998. The database includes data on key agricultural (crop and livestock), socioeconomic, agro-ecological variables for 450 districts covering 16 states in India. The final data set however, consisted of 309 districts since data for new districts formed after 1970 were apportioned back to their parent district and removed from the data set. This provides continuity in the data set allowing studying change over time.

Ordinary least squares method (OLS) was used to estimate factors influencing livestock productivity. Both log and linear forms were tried, and the better estimates of the two are reported. Estimation problems due to multicollinearity and heteroskedasticity have been addressed. Several variables among the independent variables were correlated. In such a situation, the estimating system will not breakdown because the relationship between related independent variables is not exact, but enough to cause higher variance of their estimates. It would also lead to specification errors, and the parameter estimates are sensitive to model specifications. These have been addressed in the specification of final models. Data have been corrected for heteroskedasticity by dividing each observation by square root of the estimated variance of the disturbance term. For linear models, the elasticities of the coefficients were calculated using appropriate formulae.

Livestock productivity for each district is expressed as the value of livestock production per livestock unit (LSU) at constant prices. Livestock units were calculated using standard livestock units (Pandey 1995).

A list of explanatory variables and expected relationship with productivity are shown in Table 3. The final model results are shown in Table 4. As expected livestock productivity is negatively related with work animal density. This is because in districts with high work animal density,

Table 3. Expected influence of the determinants of productivity of livestock sector, India

Explanatory variables (determinants)	Description of variables	Unit of observation	Dependent variable livestock (Rs/LU)
FSIZE	Size of land holding	Ha	+/–
MSFPER	Small and marginal land holding to total holding	%	+/–
RAIN	Normal rainfall	Mm	+
IRRI	Gross irrigated area to total area	% to GCA	+
TRACT	No. of tractors	No./000 ha of NCA	+
WORKAN	Density of work cattle cattle	No./ha	–
LUDEN	Livestock density	No./ha	–
FEED	Feed and fodder on dry- matter basis	t/Livestock Unit (LU)	+
VETY	No. of veterinary institutes per '000 LU	No./000 LU	+
MARKET	Density of regulated markets	No./10,000 sq. km of geographical area	+
ROAD	Density of total road length	km/sq. km of geographical area	+
LSHOLD	No. of livestock per land holding	No.	+/–
CBCAT	Adoption of crossbred cattle	%	+
CBSHEP	Adoption of crossbred sheep	%	+

Table 4. Determinants of livestock productivity, India

Explanatory variables	Estimated elasticities	t- statistic
WORKAN	–0.1384***	–4.87
ROAD	0.0150	0.36
FEED	0.2944***	5.37
VETY	0.2102***	4.83
CBCATL	0.0640***	4.12
CBSHEP	0.0000	0.44
LSHOLD	–0.0588	–1.34
Constant	6.7893	48.75
R^2	0.53	
Adjusted R^2	0.52	
F statistics	41.13	
No. of observations	309	

***, ** and * significant at 1, 5 and 10% probability levels.

the focus is on the dual uses of cattle, i.e., work and milk. In the process, milch animals are reared as producers of male calf, and milk production is secondary. Adoption of crossbred cattle is low because crossbred males are considered not suitable as drought animals. It should however, be noted that in districts where work animal density is high there is an optimal density beyond which its influence is negative on productivity (these findings are not reported here). Feed availability as hypothesized has a significant influence on livestock productivity (0.29). Thus, livestock productivity is closely linked with the productivity of the crop sector, particularly for by-products from food-feed and forage crops. Veterinary institutions influence livestock productivity. The effect could be indirect via improved health. Productivity is positively associated with adoption of crossbred cattle but the elasticity is only 0.06. Perhaps some of its effect is captured by the variable on veterinary institutions. Livestock holding size is negative but not significant. Similar results were obtained for cattle and buffalo productivity.

In the next section we will focus on the feed and fodder resources in mixed crop-livestock systems since its availability has an important bearing on livestock productivity.

Feed and fodder resources

Crop-residues from food-feed cereals such as rice, wheat, coarse cereals, pulses and legumes constitute 45–60% (on dry-matter basis) of total feed fed to large ruminants in India. In the dry months, until the onset of rains, stored crop residues are the only feed source. Besides crop residues cultivated green fodder crops, grasses from CPRs (Common Property Resources), pastures, forests wastelands, and fallows and Agro-industrial by-products (AIBPs) are other important sources of feed (Kelley and Parthasarathy Rao 1996, Parthasarathy Rao and Hall 2003).

The cultivation of green fodder crops is low and largely restricted to the irrigated tracts and peri-urban areas. At the all-India level less than 5% of the land area is under fodder crops (Kelley and Parthasarathy Rao 1994). The area under CPRs, is declining due to extension of cropping, encroachment for non-agricultural uses, decline in forest area due to deforestation, and decrease in fallowing due to pressure on cropland. With a growing animal population this has led to over grazing beyond the carrying capacity of the commons leading to a decline in the yield and quality of grasses (Jodha 1992, Devendra *et al.* 2000).

The use of agro-industrial by-products (grains, brans and oilcakes) is low and mainly restricted to milch animals and commercial poultry sector. The use of grain for animal feed is less than 5% (except maize), and a lion share of this goes for poultry feed.

Thus crop-residues are by far the most important source of feed and will continue to be so in the forseeable future. However, their nutritive value is low adversely effecting livestock productivity. Several technologies have been developed to improve their nutritive value like, hay and silage making, urea ammoniation and urea molasses treatment of straw etc. However, their adoption is abysmally low due to land, labour and capital constraint at the farm level and the failure to demonstrate cost-effective results has discouraged farmers' adoption of such technologies. Also, the technologies were introduced in farming systems where they were either not required, or where there were many constraints in their adoption. i.e. introduced without a proper understanding of their fitness in the farming system. Similarly, crossbreeding technology is popular throughout India i.e. the use of temperate cattle to improve the milk yields of native breeds. However, in many instances, the technology was promoted indiscriminately in all ecological regions, where it was found inappropriate to small-scale farming systems and not adaptable to the prevailing environmental conditions, including feed and fodder availability and veterinary facilities.

Thus the low productivity of livestock reflects the non-adoption of technologies or their uptake has not been sustainable. Adoption of improved technology is low, because the diverse and complex mixed farming operations are treated as a single system and the close nexus between crops and livestock ignored. Secondly, research in animal production has often highlighted component technologies within the disciplines of nutrition, health and breeding. Research has not been multi-disciplinary, and therefore has failed to take account of the interactions that occur at the farm level between genotype, nutrition, management and diseases (Thomas *et al.* 2002).

CONCLUSIONS

Small-scale mixed crop-livestock systems dominant animal production in India. Despite the emergence of commercial systems close to the demand centers much of the future growth in demand for livestock products will have to be met by the small-scale mixed systems. Here, unlike in the past growth in production will have to come from productivity increases due to pressure on resources including feed and fodder. Development of suitable infrastructure, institutions and markets would enable farmers in the hinterland to meet the growing urban demand for livestock products. Raising productivity in mixed crop livestock systems is a win-win strategy that will benefit millions of small-scale producers while at the same time protecting the environment. Thus, a comprehensive livestock development policy covering technologies, extension and delivery systems, credit, insurance and markets is the need of the hour.

REFERENCES

Birthal P S and Parthasarathy Rao P. 2004. Intensification of livestock production in India: Trends, patterns and determinants. *Indian Journal of Agricultural Economics*. 59(3): 555–65.

Birthal P S and Parthasarathy Rao P. 2002. Economic Contributions of the Livestock Sub-Sector in India. In: Birthal P S and Parthasarathy Rao P (Eds), Technology options for sustainable livestock production in India. Proceedings of ICAR-ICRISAT collaborative workshop on documentation, adoption, and impacts of livestock technologies in mixed crop-livestock farming systems in India, ICRISAT Patancheru, India. 12–19.

Birthal P S 2002. Technological change in India's livestock sub-sector: evidence and issues. In: Birthal P S and Parthasarathy Rao P (Eds.), Technology options for sustainable livestock production in India. Proceedings of ICAR-ICRISAT collaborative workshop on documentation, adoption, and impacts of livestock technologies in mixed crop-livestock farming systems in India, ICRISAT Patancheru, India. 20–40.

de Haan C, Steinfeld H and Blackburn H. 1997. Livestock and the environment: finding a balance. Report of a study coordinated by the Food and Agriculture Organization of the United Nations/ United States Agency for International Development/World Bank. UK: WREN media, Eye.

Devendra C, Thomas D, Jabbar M and Zerbini E. 2000. Improvement of livestock production in crop animal systems in agro-ecological zones of South Asia. Nairobi, Kenya: International Livestock Research Institute (ILRI).

FAO (Food and Agriculture Organization of the United Nations). 2000. Agriculture: Towards 2015/30, Technical Interim Report, April 2000. Economic and Social Department, FAO. Rome, Italy: FAO.

Jodha N S. 1992. Common property resources—a missing dimension of development strategies. Discussion paper 169. Washington, DC, USA: The World Bank.

Kelley T G and Parthasarathy Rao P. 1996. Availability and requirement of different sources of livestock feed in India with special reference to sorghum and millet straw. In Global agenda for livestock research: Proceedings for the South Asia Region Devendra C and Gardiner P (eds.) 6–8 June 1995, International Livestock Research Institute, Nairobi, Kenya. 53–65.

Kelley T G and Parthasarathy Rao P. 1994. Trends in Cultivated fodder crops in India.

In variation in the quantity and quality of fibrous crop-residues. Proceedings of a workshop, Joshi A L, Doyle P T and Oosting S J (eds.) BAIF Research Foundation, Pune.

Kumar P, Joshi P K, Johansen C and Asokan M. 1999. Sustainability of rice-wheat based cropping systems in India: socio-economic and policy issues. In Sustaining rice-wheat production systems: socio-economic and policy issues (Pingali P L, ed.). Rice–Wheat Consortium Paper Series 5. New Delhi, India. 61–77.

McIntire J, Bourzat D and Pingali P. 1992. Crop-Livestock Interaction In: Mishra S N. 2002. A note on livestock and environment in India. In Livestock in Different Farming systems in India. Birthal P S, Kumar A, Tiwari L (eds.), Agricultural Economics Research Association, National Center for *Agricultural Economics and Policy Research*, New Delhi, India. 78–83.

Paroda R S and Kumar P. 2000. Food production and demand in south Asia. *Agricultural Economic Research Review* **13**(1): 1–24.

Pandey U K. 1995. The livestock economy of India: a profile. *Indian Journal of Agricultural Economics:* **50** (3): 264–83.

Pingali P L, and Shah M. 1999. Rice-wheat cropping systems in the Indo-Gangetic plains: policy redirections for sustainable use. In Sustaining rice-wheat production systems: socio-economic and policy issues (Pingali P L. ed.). Rice-Wheat consortium Paper series 5. New Delhi, India. 1–12.

Parthasarathy Rao P and Hall A. 2003. Importance of crop residues in crop-livestock systems in India and farmers perceptions of fodder quality in coarse cereals. *Fields Crop Research:* 84: 189–98.

Rangnekar S D. 1995. Livestock feeding by women. Pages 89–101 in 7th AAAP Animal Science Congress, Bali, Indonesia.

Rangnekar S D. 1998. The role of women in smallholder rain-fed mixed farming in India. Pages 25–37 in Women in agriculture and animal production. Proceedings of a Workshop, Tune, Landboskole, Denmark.

Sere C and Steinfield H. 1996. World livestock production systems: current status, issues and trends. FAO Animal Production and Health Paper 127. Rome, Italy: Food and Agriculture Organization of the United Nations.

Thomas D, Zerbini E, Parthasarathy Rao P and Vaidyanathan A. 2002. Increasing animal productivity on small mixed farms in South Asia: a systems perspective. *Agricultural Systems* 71: 41–57.

Thomas D and Zerbini E. 1999. Increasing livestock productivity in mixed crop-livestock system in South Asia. Pages 6–21 in Proceedings of a Planning Workshop of Regional Stakeholders (Zerbini E and Parthasarathy Rao P, eds.). Patancheru, India: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Vaidyanathan A. 1998. Programme for research on mixed crop-livestock systems in South Asia: a tentative outline. Report submitted to ICRISAT, Patancheru, India. Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.