

Small farm systems to feed hungry Asia

C. Devendra

Abstract: *Small farms are an integral part of Asian agriculture. They are characterized by the preponderance and emphasis on mixed crop–animals systems across a variety of agroecological zones. Mixed farming is the backbone of agriculture, many categories of which are models of diversification, efficiency and resilience in Asia. In global terms, small farms in Asia account for an estimated 87% of all farms of under two hectares of land. About 52% of these farms have <1 ha, with the smallest sizes (0.3–0.6 ha) being found in China, Bangladesh, Sri Lanka and Indonesia. There are three types of small farms: in irrigated areas, rainfed zones and plantation agriculture. The first category greatly benefited from policy support and massive resource inputs through the 'green revolution', while the second was bypassed by it, but continues to produce the bulk of the ruminant meats and milk. The third type remains neglected. The rural poor are mainly small farmers and landless agricultural labourers; their characteristics are described in detail. Irrespective of their various definitions, the key descriptors are deprivation, subsistence, illiteracy, survival, and because of globalization, vulnerability. Data from various sources indicate some key features concerning Asian agriculture: about 83% of the agricultural area is rainfed; between 51% and 55% of the total population of cattle and goats is found here; and about 59–60% of poor livestock keepers are found on mixed farms. The development of small farms in rainfed environments is a priority for the future and affirmative action is imperative. The strategies for development include the promotion of animal production as the entry point for food production and total factor productivity; integrated use of natural resources; improved feeding and nutrition; interdisciplinary, participatory and holistic approaches to address system constraints; and strengthening access to information and delivery systems. Effective policies are urgently required to spur this initiative; these should include development policy for small farm systems; intensifying the role of animals in integrated systems; improved rural–urban marketing linkages, infrastructure and communications. The development pathways include needs-based intensification of animal production systems; improving diversification with the appropriate mix of animals that can be integrated with annual and perennial crops; ensuring access to improved technologies and markets; strengthening empowerment; promotion of cooperatives and agri-business; and sustained pro-poor initiatives to reduce poverty and hunger that are consistent with income growth, socioeconomic benefits, improved livelihoods and self-reliance.*

Keywords: *small farm systems; small farmers; mixed farming; animal production systems; rainfed areas; development pathways; Asia*

C. Devendra specializes in animal nutrition and animal production systems and is an independent consultant in international animal production. He may be contacted at 130A Jalan Awan Jawa, 58200 Kuala Lumpur, Malaysia. Tel: +60 3 7897 9917. Fax: +60 3 7983 7935. E-mail: cdev@pc.jaring.my.

The Asian region is characterized by high human population growth rates, rising demand for food supplies to meet current and projected requirements, continuing poverty, urbanization and increasing zoonosis. Of these, increased population growth and the implications for food supplies are especially critical, given that Asia alone had a human population of about 3.3 billion in 2005, which is projected to increase to about 4.6 billion by 2020. Hungry Asia thus has the awesome task of grappling with the demand for more food and its distribution, in which animal proteins rather than calories from cereals are the major concern. Concerning the latter, the projected total meat and milk consumption levels in 2020 are far in excess of anticipated supplies in Asia (Delgado *et al*, 1999). The rapid growth in the consumption of foods of animal origin is especially spectacular in East and South-east Asia, where the current and projected demand has placed major challenges and unprecedented pressure on the management of natural resources (land, crops, animals and water) and improved animal production systems (Devendra, 2004). An inquiry into where these increased food supplies are going to come from, and who is going to supply the growth in consumption, inevitably leads to a discussion and assessment of the contribution and capacity of small farming systems and small farmers in Asia.

In this context, there is a school of thought that maintains that, with increasing globalization, economies of scale, intensification and commercialization, these small farms do not have a viable future and are likely to disappear. This is unlikely to be the case in Asia because of the very large number of small farms, the production of relatively high proportions of foods of animal origin, the considerable size of the rural populations and livestock keepers therein, and continuing poverty and hunger. It has in fact been suggested that small mixed farms will remain predominant in Asia in the foreseeable future, in which crop–animal systems will see continued intensification and important growth, and that animals, in addition to production, will continue to enhance the natural resource base (Devendra, 2002). Pro-poor strategies, plus social and effective development policies, are therefore needed to address increased contributions from these farms to the food chain within an enabling economic environment to spur agricultural development.

The small farms are diverse, complex, and are found across all agroecological zones (AEZ). They are involved with various biological and livelihood diversification strategies. A large proportion of the poor population is found in small farms throughout Asia, living in the shadow of poverty and hunger, with an enduring wish for an improved and more comfortable life tomorrow. It is estimated, more importantly, that as much as 75% of the poor, or 0.9 billion, live and work in rural areas with an income of less than US\$1/day (IFAD, 2001). In the developing countries, it has been reported that 50% of the estimated four billion rural poor are dependent on livestock to maintain their basic quality of life, but their lives are being placed at risk by Western agricultural systems as domestic markets in the mega cities are targeted by Western food experts (Hodges, 2005).

This paper focuses on small farm systems and small

farmers with respect to their aspirations, characteristics, constraints, trends and their future. It is concerned specifically with characteristics of small farms and small farmers, the role and potential contribution of animals and improved natural resource management (NRM), ways of increasing productivity, pro-poor initiatives for the alleviation of poverty and food insecurity, and development pathways to achieve these objectives. The awesome need is for effective development policy to strengthen and accelerate the capacity of sustainable animal production systems on small farms to increase animal protein supplies to meet human requirements in the future. The paper emphasizes that the development of small farms in rainfed AEZs is imperative and especially important, and concludes with a discussion on strategies and development pathways that link resource use, systems perspectives to address major constraints, opportunities and policy issues.

The small farm scenario

It is important to understand and keep in perspective the meaning of small farms and their characteristics, as well as those of resource-poor small farmers and the landless.

Definition of small farms

A definition of small farms is surprisingly sparse, and perhaps symptomatic of inadequate efforts to understand the nature and characteristics of small farm systems and their relevance. Devendra (1993) defined small farms as complex interrelationships between animals, crops and farming families, involving small landholdings and minimum resources of labour and capital, from which small farmers may or may not be able to derive a regular and adequate supply of food or an acceptable income and standard of living. Lipton (2005) refers to family farms, which are operated units that derive most of the labour and enterprise from the farm family; these are, however, not the same as small farms. Small farms are typically mixed farms, and quite often these farms are involved with crops–pigs–aquaculture integration, such as in Vietnam (see Figures 1 and 2).

The traditional small farm scenario is characterized by several factors:

- There is low input use.
- Diversification of agriculture is practised.
- There is limited access to resources, services and technologies.
- They excel in the use of indigenous knowledge and traditional systems.
- A high proportion of the farmland is used for food crops, mostly for home consumption and also for food security.
- Cash crops are grown to generate income.
- A mix of animals is present, but seldom are more than two species of ruminants reared together.
- Low economic efficiency and competitiveness are evident, due mainly to low transaction costs and the use of unpaid family labour.
- There is poor access to market outlets and poor marketing arrangements.



Figure 1. A typical small farm involved in mixed farming in Vietnam.

Photo © C. Devendra.



Figure 2. A small farm engaged in crops-pigs-aquaculture integration involving small ponds, also in Vietnam.

Photo © C. Devendra.

Definition of small farmers

Compared with small farms, there are more definitions of small farmers, synonymous with the term 'smallholders'. It is important to stress that the rural poor are

predominantly small farmers and landless agricultural labourers. Adams and Coward (1972) defined a small farmer as one who had very little access to political power, productive assets and/or income streams within society. Wapenham (1979) referred to these as agricultural producers controlling no more land than they can farm without the permanent employment of non-family labour. Narayanan and Gulati (2002) characterize these as farmers (crop or livestock) practising a mix of commercial and subsistence production, or either of these, in which the family provides the majority of labour and the farm provides the principal source of income. The World Bank's Rural Strategy (World Bank, 2003) defines smallholders as those with a low asset base, operating less than two hectares of cropland.

Devendra (1983; 1993) has listed a number of features that characterize small farmers and the landless that are unique to these individuals. These include, *inter alia*:

- They are essentially resource-poor people who face geographic isolation.
- Most of these are usually found in harsh and less favourable rainfed environments.
- They continuously experience hunger and rural poverty.
- They have the capacity to adapt and survive hardship.
- They resist changes to avoid risks and capital investments.
- They have little or no access to major decision-making processes and the use of new technology.
- Being mostly illiterate, they are not interested in extension materials.
- Agricultural diversification and loss-minimizing strategies, plus livelihood diversification to earn non-farm income to support the family and the farm, are both common. In these circumstances, women tend to take over much of the decision making and management of the farm.
- They are not commercial producers of specialized livestock products and usually own 1–2 large ruminants, 4–6 small ruminants and/or a few indigenous pigs, poultry and ducks (Figure 3).
- Large ruminants are owned primarily for draught power and secondarily for meat. Animals are reared for multipurpose use, including the supply of dung and urine and transportation.
- They manage their animals as well as feed them from common property resources. Farm labour, including that from women and children, is often used for managing the animals.
- Women tend to work more hours per day than men, and together with children are often involved in household chores and in the management of small animals (Figure 4).
- They use meagre farm resources rationally and strive to achieve complementary relationships between the animal and crop components in mixed farm enterprises.
- Small farmers (except the landless) have secured tenure and can pass on their land and assets to their families and children.

The definition of small farmers also needs to include the rural landless, who are also called marginal farmers and



Figure 3. A farmer with his mixed ownership of a Yellow cow, native pigs and Yunnan black goats in Nanjian county, Yunnan province, China.
Photo © C. Devendra.



Figure 4. A farmer's wife and her children feeding native poultry in Thailand. Small animals provide critical food and nutrition security for poor rural households.
Photo © C. Devendra.

landless agricultural labourers. These individuals are essentially transhumants and nomads, who move with their flocks of camels, cattle, goats and sheep in search of feed and water (Figure 5). For many of them, it is a way of life in which they practise a variety of loss-minimizing strategies. The ownership of animals provides security and enables their survival in these less favoured environments.

Considering the various definitions, and irrespective of where the small farms are found, there are a few overriding key descriptive words concerned with the livelihoods of small farmers. Up to the mid-1990s, these were *deprivation, subsistence, illiteracy, survival*, and due to globalization and the many externalities since then, the additional keyword is *vulnerability*.



Figure 5. A landless nomad with his flock of sheep and goats on the move in search of feed and water in Rajasthan, India.
Photo © C. Devendra.

Types of small farms

There are three types of small farms in Asia:

- farms in irrigated agriculture;
- farms in rainfed areas; and
- farms in plantation agriculture.

Irrespective of the type of farm, mixed farming systems in which crops and animals are integrated on the same farm form the backbone of small farming systems in Asian agriculture. Mixed farming systems are synonymous with crop-animal systems, and are varied and integrated with annual and perennial cropping in various ways. Both ruminants and non-ruminants are involved, and the choice of one or more species is dependent on the overriding influence of preference, market dictates, potential to generate income, contribution to crop cultivation and livelihoods.

In Asia, mixed farming provides 90% of the milk, 77% of the ruminant meats, 47% of pork and poultry meat, and 31% of the eggs. The industrialized pig and poultry production systems in peri-urban areas produce the bulk of the meats and eggs. Past growth trends suggest (Steinfeld, 1998) that mixed farming systems grew half as fast (2.2% per year) compared with industrial systems (4.3% per year), and three times as fast as pastoral systems (0.7% per year). The data suggest that ruminant production in mixed farming systems will continue to be important in the future. In India, smallholders reportedly contributed over 40% of food grain production during 1990-91; they owned the majority of livestock and dominated the dairy sector (Narayanan and Gulati, 2002). The tremendous success of 'Operation Flood' in dairy

development in India is due largely to the participation of small farmers through the concerted efforts of the National Dairy Development Board of 'Operation Flood'.

Two broad categories of mixed farming systems can be identified:

- (1) systems combining animals and annual cropping in which there are two further subtypes:
 - systems involving non-ruminants, ponds and fish, eg vegetables–pigs–ducks–fish systems in Vietnam; rice–maize–vegetables–sweet potatoes–pigs–dairy cattle in China; and
 - systems involving ruminants, eg maize–ground-nuts/soya bean–goats systems in Indonesia; rice–finger millet–rice–goats in Nepal;
- (2) systems combining animals and perennial cropping in which there are again two subtypes:
 - systems involving ruminants, eg coconuts–sheep integration in the Philippines; oil palm–cattle integration in Malaysia; and
 - systems involving non-ruminants, eg oil palm–chickens integration in Malaysia.

Farms in irrigated agriculture. These are farms in essentially higher-quality or high-potential cropland where there is intensive crop cultivation, mainly cereals (rice and wheat) and secondarily cash crops. Cereal production is the predominant activity; crop yields have reached ceiling yields in which some of the produce is kept for home consumption and the rest is sold for income. The irrigated areas were the ones that greatly benefited from the 'green revolution' in Asia between 1975 and 1980. There were significant increases in per capita income and a decline in the number of people living in poverty. Increased productivity and prosperity benefited the rice farmers, but the higher agricultural growth exacerbated poverty and food security among the poor in rainfed areas. The farmers here are generally richer and have greater access to technology and services.

The green revolution was supply-led and was fuelled at that time by several key factors: sharply rising food prices, aims by governments to achieve self-sufficiency in cereals, massive irrigation schemes, and several policies to include fixed prices, credit and subsidies, most of which were supported by national governments and international donors. Since that time, cereal yield increases have been declining, as has expansion of additional land for intensive crop cultivation.

In Malaysia, detailed early surveys of 5,274 farm households in the Muda irrigated rice-growing area indicated that 87% of these were engaged in livestock keeping. Of these, 89.4% owned chickens, 47.1% ducks, 26.7% buffalo and cattle, and 7.7% goats. On average, each household had between 13 and 15 birds.

Animals are of lower importance compared with crops, but are nevertheless quite common in small farm systems. Among the animals, large ruminants, notably buffalo and cattle, are common, and are used to supply draught power for land cultivation and haulage operations, and also manure production. Swamp buffalo in the rice-growing areas of South-east Asia are used for about 80–100 days for ploughing. In Thailand, swamp buffalo



Figure 6. The rainfed lowland and upland continuum in Luang Prabang in Laos.

Photo © C. Devendra.

are used for 51–67 days (Chantalakhana and Skunmun, 2002). Small ruminants (goats and sheep) may or may not be owned, since the rice environment with its relatively abundant water supplies is not very suitable for the species. On the other hand, pigs, poultry and ducks are very common here. Ducks are especially suited to this environment where they use the available feeds and post-harvest losses of rice to great advantage.

Farms in rainfed areas. These are farms that are outside the irrigated zones, and are almost entirely dependent on rainfall for crop cultivation. They include the rainfed lowlands and uplands in a continuum (Figure 6). The land quality is very variable and as a consequence, these areas have been variously referred to as *harsh, fragile, marginal, backward, less favoured and low-potential*. In this paper, the term 'rainfed areas' will be used to embrace all these terms.

Table 1 provides information on the extent of the rainfed areas (CGIAR/TAC, 2000). In Asia, rainfed areas (marginal + arid lands + forests and woodlands) account for 83.1% of agricultural lands, compared with 16.6% of favoured land. Marginal and arid lands alone constitute 48.5% of the total area. Additionally, about 63% of the rural population is found in the former, compared with only 37% in the favoured areas. It is of interest to note in this context that in 1993 in India, 42% of the rural poor lived in low-potential rainfed areas, 16% in irrigated

Table 1. Distribution of land types by region.

Region	Land type (% of total land)				Rural population living in favoured lands (%)
	Favoured	Marginal	Sparsely populated arid lands	Forest and woodlands	
Asia	16.6	30.0	18.5	34.6	37.0
Latin America and Caribbean	9.6	20.3	8.1	61.9	34.0
Sub-Saharan Africa	8.5	23.1	24.6	43.7	27.0
Near East and North America	7.8	22.6	65.8	3.9	24.0
Total (105 countries)	10.7	24.0	25.9	39.4	35.0

Source: CGIAR/TAC, 2000.

areas, and 42% in high-potential rainfed areas (Fan and Hazell, 2000).

It is important to stress that some of the rainfed areas are potentially very useful, such as the lowland areas immediately outside the irrigated zones. In comparison with farms in the high-potential, favoured or irrigated areas that significantly benefited from various policy support, the rainfed areas were bypassed by the green revolution and had very limited access to the many policy issues and resource inputs of national governments. Quite justifiably therefore, official support (similar to that of the irrigated areas) is now necessary to give greater emphasis to these regions. With improved technological interventions, increased resource use and opportunities for improved NRM and animal production, these areas can produce more food in the future (Devendra, 2000a).

The rainfed AEZs of relevance are as follows:

- rainfed temperate and tropical highlands – mainly the Hindu-Kush/Himalayan region;
- rainfed humid/subhumid tropical systems – mainly countries in Indo-China, South-east and East Asia, and the Pacific Islands, parts of South Asia to include Bangladesh and Sri Lanka; and
- rainfed arid/semi-arid tropical systems – mainly countries in South Asia, excluding Nepal and Bangladesh.

Among these, rainfed humid/subhumid and rainfed arid/semi-arid tropical systems are priority AEZs. Table 2 gives some indication of the household characteristics, biophysical data, and patterns of farming systems on five rainfed locations in China, Indonesia, the Philippines, Thailand and Vietnam. The average annual rainfall was between 1,500 and 2,300 mm; rice-based cropping systems were common, but this also included other annual crops and tree crops. Both ruminants and non-ruminants were reared, and the presence of both animal and crop diversity provided a variety of crop–animal interactions (Devendra and Thomas, 2002), the effects of which on productivity, people's livelihoods and sustainable agriculture provide major opportunities for research and development activities. The overriding major constraint was the 5–7 months of dry periods. There was a 10–25% level of contribution by animals to total farm income (Devendra, 2005).

A few countries, for example China, India and Indonesia, have given priority to the development of these rainfed areas. In China for example, the north-

western region is given priority for the intensification of agricultural production and creation of 'climate-free' agriculture in the grasslands through irrigation from underground aquifers, with the objective of making the area a bread and -meal basket to meet China's growing demand for protein-rich diets. However, population pressures on these grasslands have been increasing, with resultant increased poverty rates, degradation and dust storms (MEA, 2005).

Farms in plantation agriculture. These are farms that are found within large plantations that usually involve tree crops such as coconuts, citrus, oil palm and rubber. Relative land areas are therefore larger because of the tree crops. These include government settlement schemes such as the Federal Land Development Authority (FELDA) in Malaysia, and the transmigration schemes in Sumatra, Indonesia. In the latter, five hectares of land parcels are allocated to resettle people away from Java through the management of rubber-based agriculture and animal production. The animals reared are beef cattle, small ruminants and poultry.

Integrated tree crops–ruminants production systems are underestimated in Asia. These systems have much potential to promote effective NRM, productivity gains and sustainability. In this context, integration with coconut systems in the Philippines (Figure 7), oil palm in Malaysia (Figure 8) and rubber in Indonesia are good examples.

Size of holdings, trends and contribution

The small size of farm holdings is one of the characteristic features of Asian farming systems. Nevertheless, there is considerable variation between AEZs and countries, which is reflected in the various definitions used to describe both small farms (Table 3) and small farmers.

The size of farms varies from country to country, but specific attempts have been made to classify small farms, in which the yardstick of less than 2 ha has often been used. The classification of farms is also influenced by land quality. In India for example, small farmers, marginal farmers or agricultural labourers are those with 2–4, 0.8–2 and < 0.8 ha of dryland respectively. In the Philippines and Thailand, small farms have land sizes of 2.8 ha and 1.2 ha respectively. Using a definition of a small farm as having a land area less than 2 ha, it has been reported that an overwhelming majority (87%) of the 470 million small farms worldwide is found in Asia (Nagayets, 2005). It was

Table 2. Some household attributes and biophysical characteristics in rainfed farming systems in five countries in South-east and East Asia.

Item	Vietnam	Thailand	Indonesia	Philippines	China
<i>Household attributes</i>					
Average farm size (ha)	2.59 ± 1.97	5.24 ± 2.74	0.55 ± 0.73	1.26 ± 0.45	0.27 ± 0.12
Household size (persons)	4.94 ± 1.74	4.79 ± 2.08	4.46 ± 1.54	5.52 ± 2.33	4.73 ± 1.29
Percentage of farms managed by women	28.4	31.6	4.2	30.0	26.0
<i>Biophysical characteristics</i>					
Location	Dong Tam, Bin Phuoc	Amphur, Muang Maharakham	Dangiang, Cilawu, Garut	Don Montano, Umingan, Pangasinan	Bixi Xiang, Nanjian, Yunnan
Mean annual rainfall (mm)	2,170	1,500	2,200	2,300	760
Dry season (months)	6	6–7	5–6	6	7
<i>Farming systems</i>					
Predominant crop–animal systems	Rice-based beef cattle production	Rice-based dairy cattle production	Rice-based cattle fattening and sheep raising	Rice-based beef cattle and goat production	Wheat/maize-based beef cattle and goats production
Predominant animal species ¹	BC, Pi, Po	DC, Pi, Po	BC, Bu, S, G, Fi	BC, Bu, G, Pi, Po	BC, Bu, G, Pi, Po
Number of animals (TLUs) ²	0.67 ± 1.69	7.34 ± 4.32	0.70 ± 0.78	2.26 ± 1.97	1.07 ± 0.73
Main crop–animal interactions	Crop residues as feeds, use of draught animals	Crop residues as feed, manure as fertilizer, use of draught animals	Crop residues as feed, manure as fertilizer	Crop residues as feed, manure as fertilizer	Crop residues as feed, manure as fertilizers, use of draught animals
Contribution of livestock to total income (%)	13	10–20	10–15	15–20	20–25

¹ BC = beef cattle, DC = dairy cattle, Bu = buffaloes, S = sheep, G = goats, Pi = pigs, Po = poultry, Fi = fish.

² TLU = tropical livestock unit, equivalent to a ruminant animal of 250 kg body weight. Only ruminant species have been considered for its estimation, according to the following equivalencies: cattle and buffalo = 1.0, sheep and goats = 0.01; in all species, mature male = 1.0; mature female = 0.75, growing animal = 0.5; pre-weaned animal = 0.25.

Source: Devendra, 2005.

further estimated that China alone accounted for about 40.2% of these farms, followed by India (23%). The average farm size in Asia is reported to be 1.6 ha (von Braun, 2005), but the average size of small farms in most countries is much lower than this (Table 3). In Asia also, some 52.7% of farms across many countries have <1.0 ha, with the smallest farm sizes of 0.3 ha being found in Sri Lanka, 0.4 ha in Indonesia, and 0.60 ha in Bangladesh. In China, Chuanmin and Falla (2006) have recently reported that in the year 2000, the average farm size of over 241 million farms was 0.57 ha.

Of increasing concern is the trend towards decreasing farm sizes in all countries, due to the subdivision of existing land. Table 4 gives an idea of this trend. Without exception, farm landholdings are decreasing and will continue to do so. There are inadequate data on this trend with specific reference to small farms in rainfed areas, but there is no doubt that the trend is also found in these areas.

There appear to be few data on the extent of the contribution by small farms to food production, especially by animals. However, remembering that mixed farm systems are the predominant production systems in Asia, and that the bulk of the milk, ruminant meats and a fair share of non-ruminant meats and eggs come from these systems, it follows that the contribution by small farms to

foods of animal origin is quite significant. With crops, it is pertinent to note from FAO (2005) data that, with farms of < 2 ha of land, the proportion of cropland was 69% in Bangladesh (1996–97), 58% in China (1997) and 36% in India (1995–96).

Small farms and poverty

The first of the eight Millennium Development Goals concerns poverty. The objective is to eradicate extreme poverty and hunger by halving the proportion of people whose income is less than US\$1/day and those who suffer from hunger (UN, 2001). Small farm systems, and especially those in the harsher areas, have a relatively large proportion of poor people concentrated in them, and addressing both poverty and hunger are therefore closely linked with improved productivity from these farms. The extremely poor own less land, especially irrigated land, and depend on subsistence agriculture for a large part of their income. Data from Bangladesh indicate that poverty is correlated with the amount of land a household controls (Human Development Report, 2001). The severity of poverty and hunger appears to be associated with the size of farms, and Singh (2004) reported that in India the incidence of poverty and hunger among those farmers whose landholdings were under 0.5 ha was 38% and 32%



Figure 7. Integration of sheep with coconut production in the Philippines.

Photo © C. Devendra.



Figure 8. Cattle integrated with oil palm in Malaysia.

Photo © C. Devendra.

respectively. With larger farms of more than 4 ha, the incidence was reduced by 13% and 12% respectively.

In the rural areas, poverty is a rural dilemma. The rural poor depend to a very large extent, directly or indirectly, on the farm for at least four major objectives: incomes, building assets, food security and improved livelihoods. Pro-poor development objectives therefore need to make a concerted effort to address these objectives and the widening gap between the 'haves' in the high-potential areas and the 'have-nots' in the rainfed zones. Development efforts and investment aid thus remain a major challenge for the development community, since the alleviation of poverty and increased resourcefulness will influence increased productivity.

These poor people are disadvantaged in a multitude of ways, the elements of which consist of various interrelated issues, *inter alia*, including: chronic hunger, malnutrition and ill health, inadequate or no access to most amenities, deprivation and despair. These together result in a continuing syndrome of a poverty-adaptation-fragile lives-little hope-low life expectancy complex in which the potential to be fully participatory and productive is significantly reduced. Poor farmers long for and dream of dignity, self-reliance and empowerment (Devendra and Chantalakhana, 2002).

Table 5 presents the proportion of poor livestock keepers by production system and region, and several observations are relevant to this. First, across regions, mixed rainfed systems had the highest proportion of poor

Table 3. Variation in the size of small farms in some countries.

Country	Definition
Bangladesh	(a) Subsistence farmers/croppers < 0.4 ha (b) Viable and potentially viable owners, 0.4–0.8 ha
India	(a) Small farmers, 2–4 ha of dry land (1 ha dry land = 0.8 ha of wetland) (b) Marginal farmers, 0.8–2 ha of dry land (c) Agricultural labourers, < 0.8 ha of dry land
Indonesia	(a) Java, 0.66 ha (b) Average size, 1.2 ha
Korea	< 1 ha
Malaysia	(a) Rice faros, 1.6–1.7 ha (b) Rubber smallholdings, 2.1 ha
Nepal	(a) Terai, 4 bighas (2.5 ha) (b) Hills, 1.75 bighas (1.0 ha)
Philippines	Average size, 2.8 ha
Sri Lanka	(a) Agricultural households, 1.2 ha (b) Rice-cultivating households, 0.3 ha
Thailand	Non-canal-irrigated areas, 2.4 ha

Source: FAO, 2001, 2004.

Table 4. Trends in the average size of farms in selected countries.

Country	Year	Average farm size (ha)
China	1980	0.6
	1990	0.4
	1999	0.4
India	1971	2.3
	1991	1.6
	1995–96	1.4
Indonesia	1973	1.1
	1993	0.9
Nepal	1992	1.0
	2002	0.8
Pakistan	1971–73	5.3
	1989	3.8
	2000	2.1
Philippines	1971	3.6
	1991	2.2

Source: FAO, 2001, 2004; data on China are from Fan and Chang-Kang, 2003.

livestock keepers. Within these systems and within regions, South Asia and South-east and East Asia accounted for 59–60% of total poor livestock keepers. Mixed irrigated systems were the next highest, with 29–33.7%. The higher number of poor livestock keepers in the mixed farming systems in rainfed areas is consistent with the higher proportion of rural poor found in the combined marginal, arid lands, forests and woodlands (Table 1).

About 14% of poor livestock keepers are in the landless category, mainly in the arid and semi-arid regions (Table 1), and are found mainly in the arid and semi-arid Hindu-Kush Himalayan region, Mongolia, China, Pakistan and India. Animal production involves zero-grazing practices and extensive systems that are associated with resource-

Table 5. Proportion of poor livestock keepers within production system, by region (%).

Production system	Developing countries	Sub-Saharan Africa	N Africa and Near East	South Asia	East and S E Asia	Latin America and Caribbean
Grassland-based systems	7.1	13.1	14.3	2.5	1.8	9.0
Mixed rainfed systems	66.0	77.9	56.6	60.1	59.3	67.9
Mixed irrigated systems	18.5	0.4	16.9	33.7	29.0	3.6
Landless	8.4	8.5	12.1	3.7	9.9	19.5

Source: Thornton *et al*, 2002.

poor nomads, transhumants or agricultural labourers and seasonal migrants with small ruminants, cattle and camels. The movements are annual cycles that are triggered by reduced feed and water supplies, inadequate market opportunities and loss-minimizing strategies (Devendra, 1998). This is also a way of life for the poor, and the ownership of animals enables survival and also food and financial security.

Within Asia, the largest numbers of poor people are found in India. The country has reduced absolute poverty from about 55% in the 1970s to about 35% today. The percentage of rural poor out of the total poor is about 79%, as a consequence of which, the major focus is on this rural sector and ways to stimulate agricultural growth to overcome persistent poverty. Associated with this situation, however, are the very high infant mortality rates, a high percentage of infants not surviving to age 40 years, and underweight children under the age of five years (Human Development Report, 2001).

Role and contribution of animals

Animals play an important role in small farm systems and make a number of valuable contributions. They occupy an important economic and ecological niche in these systems throughout Asia. Animals are widely owned by small farmers for a variety of advantageous reasons (Devendra, 1983; Chantalakhana, 1990):

- diversification in the use of production resources and reduction of socioeconomic risks;
- promotion of linkages between system components (land, crops and water);
- generation of value-added products (eg meat, milk, eggs and skins);
- income generation, investment, insurance and economic security;
- supply of draught power for crop cultivation, transportation and haulage operations;
- contribution to soil fertility through nutrient cycling (dung and urine);
- prestige, social and recreational values;
- contribution to sustainable agriculture and environmental protection; and
- development of stable farm households.

The role and contributions of animals in small farms are far more varied and complex than in specialized commercial farms due to the close and varied relationships with farm families, interactions with crops, social values and prevailing agricultural systems. The

multipurpose roles and contributions by animals generally fall into four categories:

- (1) household benefits;
- (2) increased productivity in integrated farming systems;
- (3) sustainability of agricultural systems and environmental integrity; and
- (4) enhancement of rural and social stability.

The many functions of animals are well known; however, there are important additional features and implications concerning the role of animals in small farms. These are as follows:

First, the irrigated areas are home to the majority of swamp buffaloes, some cattle, pigs and poultry, and the peri-urban and urban areas have the bulk of the landless industrial pig and poultry production systems. Outside of these areas and within the rainfed lowlands and uplands, 51–55% of the total population of cattle and small ruminants in Asia is kept (TAC, 1992), including smaller populations of native pigs and poultry. In the latter situation therefore, the value of these species and their contributions increase with the decreasing quality of the ecosystem in the face of harsher biophysical factors. In these circumstances, the ownership of animals is vital for survival, financial ('banks on hooves') and food security, production of dung to sustain crop production, and enhancement of the natural resource base.

Second, the interactions with the environment in rainfed environments are much more serious, such as in overgrazing, 'slash and burn' issues and depletion and degradation of the natural resources. Improved production systems that involve controlled management of grazing animals are therefore vital to maintain environmental integrity.

Third, the presence of a relatively large proportion of ruminant animals in the rainfed areas clearly implies a need for their development and for an emphasis on these areas. A focus on improved animal production systems is therefore a most important prerequisite for promoting total factor productivity in these same areas.

A fundamental prerequisite for developing and increasing productivity from animals in the rainfed areas, promoting efficient natural resource management and protection of the environment, is the need to consider research and development in holistic terms. A holistic approach backed by systems perspectives is vital for dealing with the numerous positive and negative interactions and heterogeneity of small farm systems.

Strategy for developing small farms: addressing major constraints and opportunities

The strategy for the development of small farms needs to address several issues and constraints in order to pursue opportunities for productivity enhancement. These are as follows:

Institutional support for research and development

The first requirement is a belief in the potential importance and contribution of small farms, and therefore their development in Asia in the future. Institutional commitment, support for and a reorientation of research and development philosophy and recognition of the complexity of the issues involved are fundamental to this endeavour. An agenda for research and development prerogatives is required that includes the following:

- programme focus and target AEZs;
- a clear set of objectives;
- prioritization of effort for multidisciplinary and participatory approaches that respond to the needs of small farmers;
- linkages with development agents and the private sector;
- a time frame;
- potential biological and socioeconomic benefits and impacts; and
- potential 'spillovers' to other locations and regions (Alston, 2002), including trans-regionally.

Without these considerations, much needed improvements in the productivity of small farms and livelihoods of small farmers are unlikely to be achieved.

Natural resource management

Understanding the natural resource base is essential for its effective management and to optimize production. NRM involves the components (land, crops, animals and water), as well as their synergies, the interactions of the components, and their positive and negative implications. Associated aspects related to this task include the following:

- importance of indigenous knowledge and traditional methods used by farmers to meet their objectives and needs;
- biodiversity;
- community-based NRM practices;
- integration of NRM components and production systems;
- productivity-enhancing and needs-based technologies;
- issues of sustainability and sustainable development; and
- development of multidisciplinary models and partnerships that target the development of small farm systems.

The benefits of improved NRM, technology application and opportunities for productivity enhancement are many (Devendra, 2001). This is clearly reflected in a recent review of the benefits of crop-animal interactions and attendant economic advantages from 31 studies in 11 countries concerning small farms across a variety of AEZs, mixed farming systems, various species of animals,

and both annual and perennial crops in Asia (Devendra, 2007). The range of farming systems involved, and more particularly the application of needs-based new technologies in individual countries, demonstrate what can also be achieved in terms of the types and extent of benefits in small farms. Effective NRM has necessarily to be very much participatory, and needs to build on indigenous knowledge and traditional systems. The need for trust, reciprocity and connectedness in institutions in the collective management and improvement of natural resources is equally important and has been emphasized (Pretty, 2003).

Targeting more effective NRM in small farms is therefore urgent and is also justified by the following factors:

- the need for increased productivity in Asia with its massive human populations, population growth rate and poor people;
- distinct opportunities for productivity enhancement based on the knowledge already available;
- focusing more attention on the application of locally generated agricultural technologies and their spillovers, which will promote increased self-reliance;
- investments in productivity-enhancing research and development, which are decreasing and difficult to obtain; and
- effective use of NRM, which also has the advantage of preserving indigenous knowledge, traditional systems and biodiversity.

Targeting research and development of rainfed areas

The rationale and justification for targeting the rainfed areas in Asia are related to three important reasons: inadequate availability of arable land, the need to increase productivity from animals to match projected human needs, and the alleviation of poverty (Devendra, 2000a). The decreasing availability of arable land with human population increase is reflected in the projected decrease from between 0.17 and 1.0 ha/person in 1988/90 to between 0.05 and 0.30 ha/person by 2010 (FAO, 1998). Inadequate arable land is associated with the following reasons:

- demand for agricultural land to meet human needs, eg housing, recreation and industrialization;
- expansion of crop production to ceiling levels;
- increasing and very high animal densities;
- increased urbanization and use of arable land; and
- growing environmental concerns due to very intensive crop production, eg acidification and salinization with rice cultivation, and human health risks due to expanding peri-urban poultry and pig production.

Poverty is a major concern since the rainfed areas also have large populations of the poorest of the poor, the vast majority of whom live below the US\$1/day yardstick. It is estimated that about 678 million of the rural poor keep livestock in developing countries, and this represents two-thirds of the rural poor (Livestock in Development, 1999). The poverty dimension includes eight elements (IFAD, 2001): material deprivation, lack of assets, isolation, alienation, dependence, lack of decision-making power, vulnerability to external shocks, and insecurity.

These circumstances place much stress on the use of

natural resources, and thus force a need to look beyond the use of arable land in the irrigated areas, and to focus much needed attention on the more difficult rainfed areas. For example, rainfed lowland and upland areas are underutilized. This is reflected in the availability of approximately 141×10^6 ha of land, or 43% of the total arable land in Asia (TAC, 1992).

The rainfed areas have been constrained by many factors, such as roads and market access, and hence have been relatively underutilized and also bypassed by research and development. The development of rural roads is especially significant, and in China for example, it has been shown that every yuan invested in low-quality roads yielded five yuan of rural non-farm gross domestic product (GDP). Moreover, low-quality roads raise more people out of poverty per yuan than high-quality roads (Fan and Chan-Kang, 2005). Increased rural roads also contribute to market access. Water is another constraint, and without adequate irrigation systems, rainfed areas have not been able to increase productivity and capacity. These constraints can however be overcome by increased research and development attention, technology delivery and market-oriented production systems. It is also important to note that in studies in India (Fan, Hazell and Thorat, 2000) and China (Fan, Zhang and Zhang, 2000), the returns on investment are very much higher in these areas compared with areas that have benefited from the green revolution.

The strategy for the development of small farms must therefore give priority to rainfed areas, especially to the potentially more important locations. Within these, animal production can strategically serve as the entry point to address food production, pro-poor initiatives, collective management and improvement of the natural resources that are needs-led. Interdisciplinary research and development efforts that target AEZs serve to address the major constraints and opportunities.

The systems approach and interdisciplinarity

A notable and consistent weakness of the research and development process and programmes in most national agricultural systems concerned with animal production in Asia is the near absence of the use of the systems approach. Much of the research continues along strong disciplinary lines without reference to the needs of the small farm systems and the AEZs where they are found (Devendra, 1996, 2006). Despite the dominant emphasis on mixed farming in Asia, research on crop-animal systems is seldom integrated, and with rare exceptions, very few institutions recognize the importance of training in systems research. As a consequence, the complex and interrelated systems-based problems in crop-animal systems are not addressed in holistic terms. This tendency explains why improved productivity from animals in small farm systems is slow to be realized. To a very large extent, the same reasons also apply to the general neglect of the rainfed areas, the inadequate productivity from small farm systems therein, and the contribution from animals.

The systems approach requires multi- and interdisciplinary interpretation of the different components of the system and biophysical environment, identified through detailed analyses of the constraints,

needs and opportunities. These ensure that the individual components, interactions and contributions can focus on the whole system. Considering the complexities of small farm systems, the heterogeneity of the biophysical environment, and the various types of mixed farming activities therein, systems perspectives are therefore of paramount importance in improving understanding and development of the increased contribution of these farms.

The methodology for systems research is distinct, and follows several sequential steps:

- (1) site selection;
- (2) site description and characterization (diagnosis);
- (3) planning of on-farm research;
- (4) on-farm testing and validation of alternatives;
- (5) dissemination of results; and
- (6) impact assessment.

The systems approach needs to be backed by other important requirements:

- recognition of the importance of interdisciplinary participatory approaches;
- formulation of research programmes that have community-based participation to set a common agenda and create ownership (this should involve both production and post-production systems);
- programmes that are needs-led and have institutional and structural commitment;
- establishment of effective participatory planning, inter-institutional coordination and collaboration, research management, dissemination of information, and resolution of feedback issues;
- long-term commitment to achieving impacts; and
- training in agricultural systems and systems methodologies at various levels.

Associated with these methodologies, much more can also be done to improve the socioeconomic understanding of the rural landless poor. This includes taking into account *inter alia* their way of life and aspirations; their seasonal movements together with their moving flocks of camels, cattle, goats and sheep; reasons for the choice and extent of animal ownership; constraints to their livelihoods; and loss-minimizing strategies. These and the foregoing issues justify further research investments to improve the situation.

Feed resources and nutrition

Foremost among the constraints to animal production are feed resources and nutrition, which constitute the major constraint throughout South-east Asia (Devendra *et al*, 1997) and South Asia (Devendra *et al*, 2000). The strategy for feed resource use needs to take cognizance of the following interrelated issues (Devendra, 2000b):

- knowledge of the totality of available feeds (grasses and forages, crop residues, agro-industrial by-products and non-conventional sources);
- appropriateness and effective use within production systems;
- feeds and their use should be identified with farming systems and self-reliance; and
- potential promotion of linkages between rural and peri-urban areas in the use of production inputs,

intensification, nutrient flows, and marketing of produce that is consistent with environmental integrity.

Given the critical long dry seasons and feed shortages in these environments, together with the possibilities of increasing feed production to overcome the shortages, the synchronization of feed availability to match species requirements, along with methods of conservation, are major opportunities. An example of this approach includes food–feed cropping, eg rice and mung bean, cassava and cowpea (Devendra, Sevilla and Pezo, 2001), forage production in rice bunds and under tree crops, alley cropping, planting tree legumes such as *Gliricidia* or *Leucaena* for forage production, and the use of multi-nutrient block licks (MNBL). Other options include the development and promotion of dual-purpose (seeds and forage) sorghum, millet and groundnut with resistance to foliar diseases and higher biomass yields in southern India (Blummel *et al*, 2003), especially to support dairy production, and reduced fallows. The resolution of constraints can produce significant impacts on increased *per animal* performance and improved livelihoods of resource-poor farmers, and can enhance existing productivity gaps in these areas. The final objective of these improvements should be the development of sustainable all-year-round feeding systems.

Access to technologies and delivery systems

Access to improved and appropriate technologies is a major constraint with small farmers. The problem is particularly manifested among small farmers and small farms in the rainfed areas that have been bypassed by the green revolution. These same areas are also often remote and have poor communications, resulting in further difficulties. For these and other reasons, research programmes have tended to ignore these situations. Associated with access to improved technologies are weak delivery systems, which do not facilitate effective technology transfer and adoption to accelerate productivity. This is a major weakness in research programmes that do not formulate and ensure participatory adaptive research and on-farm development activities or strengthening of effective research–extension linkages to ensure maximum adoption.

It is of interest to note that analyses of seven country case studies (Meinzen-Dick *et al*, 2004) have shown that three main factors affected technology adoption:

- vulnerability – whether the technologies were expected to increase or decrease people’s vulnerability to loss of income, bad health, natural disasters and other factors;
- assets – whether farmers had the assets necessary for technology adoption – especially if they were poor; and
- institutions – whether institutions (such as agricultural extension services, government policies, non-governmental organizations, private sector gender roles, markets for inputs and outputs, etc) encouraged or discouraged adoption and represented the interests of poor people.

Markets and marketing

Small farmers have major problems coping with a range of difficulties in the face of the complexity and general inefficiency of the prevailing marketing chains. Foremost

among these is access to marketing and to the marketing chain. At present, inadequate access to market outlets and weak marketing arrangements represent a major constraint to the *production to consumption systems* and to the owners and producers of animals. As a consequence, small farmers are often denied compelling opportunities and economic benefits. The market chain involves rural, peri-urban, urban and international markets, and a major challenge will lie in ways to link small farmers with these markets and marketing systems.

Rural markets are especially important to rural communities and their households, and are also used for the sale of live animals for slaughter in the urban areas. In order to provide good links between rural and urban markets, appropriate infrastructural and communication facilities must be in place, in addition to collection and processing centres. Without improved marketing and transport systems, the prevailing systems constitute major constraints to the sale of animals and products from small farms. Because of the greater market demand for animal products in urban areas, transport facilities become essential. Urban markets are the outlets for exports, and promote international trade.

Considerable opportunities exist for participation in the international trade of meats in the Middle East region. To compete in world markets, however, quality standards, processing and storage facilities become essential. Additionally, for the Muslim world and the huge markets in the Middle East, meeting ‘halal’ standards is also vital. Associated with international trade is the impact of globalization and the lowering of tariff and non-tariff barriers, involving opening up market opportunities for countries on the one hand, and on the other, severe competitiveness for low-cost products. Efficient production, post-production to consumption and marketing systems are therefore crucial to maintain a sustainable and competitive position.

Policy issues

A number of policy issues need to be resolved to support the future development of small farms and increased contributions from them. Such policies will also be supportive of increased investments in their development as well as pro-poor initiatives. For reasons of brevity, these will not be discussed in detail, but are identified *inter alia* as follows:

- A first essential is affirmative development policy for improved understanding of small farms, current situation and trends, and potential future contributions.
- The aspirations of small farmers and the syndrome of a poverty–adaptation–fragile lives–little hope–low life expectancy complex will need new attention on account of globalization and their vulnerability. Socio-economic research can make a major contribution here.
- Associated with the above is the role of animals as the entry point for development, especially in the more difficult rainfed environments outside of the irrigated areas that have been bypassed by the green revolution.
- Research and development on the complexity and heterogeneity of small farm systems, NRM and crop–

soil–animal interactions must necessarily be interdisciplinary and holistic. At present, knowledge of systems perspectives and adaptive research at the farm level are major limitations in most countries. These represent major and urgent training needs at the college and university levels.

- Animal production in small farm systems has to be seen in the broader context of production–post-production–consumption systems.
- Among the ruminant production systems, integration with tree crops, despite the economic benefits of added value, is still underestimated. Policy interventions are required to stimulate the development of more integrated systems with animals, for example, through tax incentives, and also to encourage increased private sector investment.
- Policy is required to support micro-credit schemes, access to markets and public services.
- The market chain involves rural, urban and international markets. Rural markets are especially important to rural communities and for the sale of live animals for slaughter to urban areas. At present, the rural–urban market linkages are weak, and appropriate policies are required to provide improvements to these, collection and processing centres, as well as infrastructural and communication facilities, and to provide links to international markets.

Development pathways

Considered together, the challenges for the future of small farms in Asia include the following, *inter alia*:

- Based on constraint analyses through community-based participation, there should be a focus on priority needs to improve animal production systems.
- Diversification should be improved through the appropriate mix of animals with annual or perennial crops appropriate to mixed farming to intensify production in rainfed areas.
- Create increased access to information, improved technologies and delivery systems, which can potentially impact on total production increases, socioeconomic benefits, improved livelihoods and sustainable development.
- Strengthen empowerment, to include informal training at various levels, gender equity and also effective dissemination of information.
- Promote the formation of cooperatives, farmer organizations, focus groups and farmer-managed revolving funds to enhance decision making and resource planning. These enhance reduced transaction costs and improved marketing to obtain better returns for the produce. The successful Anand model of India's 'Operation Flood' involved making farmers shareholders in the whole chain of marketing and processing milk, and is worthy of note and emulation.
- Promote pro-poor initiatives that are consistent with income growth, socioeconomic benefits, improved livelihoods and self-reliance.

Cooperative development is largely dependent on the capacity of farmers to be self-reliant so as to benefit from economies of scale, bargaining power, competitiveness in

agribusiness, as well as reduced market risks.

Agricultural cooperatives are very variable in Asia, and these remain to be more fully developed in many countries. In China for example, cooperatives are very limited, and a nationwide need for their establishment to overcome natural and market risks has recently been suggested (Chuanmin and Falla, 2006). Fully developed cooperatives are dynamic, contribute significantly to rural development, and can enable small farm systems to respond to market dictates and consumer needs.

Conclusions

Small farm systems will remain an integral part of Asian agriculture and will continue to occupy a predominant position in food production within an overwhelming panorama of varied agricultural activities in the various AEZs. These small farms are models of diversification in NRM and resilience. They will continue to play an important contributory role in the production of a high proportion of ruminant meats and milk in particular, and in enhancing the natural resource base. They will also help alleviate poverty, hunger and food insecurity for the sizeable populations of rural poor, despite the threat of increasing globalization, economies of scale, intensification and commercialization in the foreseeable future. There are major constraints to their development, of course, but there are also compelling opportunities and economic benefits that involve community-based management of natural resources. Social and effective development policies are also needed that can together stimulate increased contributions from these farms to the food chain – within an enabling economic environment – and can spur agricultural development.

References

- Adams, D., and Coward, E. W. (1972), *Small Farmer Development Strategies*, Agricultural Development Council, New York.
- Alston, J. (2002), 'Spillovers', *Australian Journal of Agricultural Research and Resource Economics*, Vol 48, pp 315–336.
- Blummel, M., Zerbini, E., Reddy, B. V. S., Hash, C. T., Bidinger, F., and Khan, A. A. (2003), 'Improving the production and utilisation of sorghum and millet in livestock feed: progress towards dual-purpose genotypes', *Field Crops Research*, Vol 84, pp 143–158.
- CGIAR/TAC – Consultative Group on International Agricultural Research/Technical Advisory Committee (2000), 'CGIAR priorities for marginal lands', CGIAR, Washington, DC (mimeograph).
- Chantalakhana, C. (1990), 'Small farm animal production and sustainable agriculture', *Proceedings III Asian–Australasian Animal Science Congress, 27 May–1 June, Taipei, Taiwan*, Vol 2, pp 39–58.
- Chantalakhana, C., and Skunmun, P. (2002), *Sustainable Smallholder Animal Systems in the Tropics*, Kasetsart University Press, Bangkok.
- Chuanmin, S., and Falla, J. S. (2006), 'Agro-industrialization: a comparative study of China and developed countries', *Outlook on Agriculture*, Vol 35, No 3, pp 177–182.
- Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., and Courbois, C. (1999), 'Livestock to 2020. The next food revolution', *Food, Agriculture and the Environment Discussion Paper No 28*, International Food Policy Research Institute, Washington, DC.
- Devendra, C. (1983), 'Small farm systems combining crops and animals', *Proceedings of Fifth World Conference in Animal Production*, 14–18 August, Tokyo, Japan, Vol 1, pp 173–191.

- Devendra, C. (1993), *Sustainable Animal Production From Small Farm Systems in South East Asia*, FAO Animal Production and Health Paper No 106, FAO, Rome.
- Devendra, C. (1996), 'Present status of research and development and institutional considerations for animal production systems in the Asia-Pacific region', *Proceedings of V111 Asian-Australasian Animal Science Congress, 13-18 October, Seoul, Korea*, pp 28-34.
- Devendra, C. (1998), 'Improvement of small ruminants production systems in rainfed agro-ecological zones of Asia', *Annals of Arid Zone*, Vol 37, No 2, pp 215-232.
- Devendra, C. (2000a), 'Animal production and rainfed agriculture in Asia: potential opportunities for productivity enhancement', *Outlook on Agriculture*, Vol 29, No 3, pp 161-175.
- Devendra, C. (2000b), 'Strategies for improved feed utilization and ruminant production systems in the Asian region', in Stone, G. M, ed, *Proceedings of 9th Asian-Australasian Animal Production Congress, 3-7 July, Sydney*, Vol B, pp 51-58.
- Devendra, C. (2001), 'Productivity enhancement in animal production systems in Asia', in Virmani, S. S., Brar, D. S., Mamaril, C. P., and Arboleda, C. R., eds, *Proceedings of the Asian Agricultural Congress, 24-27 April, Manila*, pp 110-141.
- Devendra, C. (2002), 'Crop-animal systems in Asia: future perspectives', *Agricultural Systems*, Vol 71, Nos 1-2, pp 179-186.
- Devendra, C. (2004), 'Meeting the increased demand for animal products in Asia: opportunities and challenges for research', in *Responding to the Livestock Revolution*, Publication No 33, British Society of Animal Science, Penicuik, pp 209-228.
- Devendra, C. (2005), 'Improvement of crop-animal systems in rainfed agriculture in South East Asia', in Rawlinson, P., Wachirapakorn, C., Pakdee, P., and Wanapat, M., eds, *Proceedings of International Conference on Livestock-Crop Systems to Meet the Challenges of Globalisation, 14-18 November, Khon Kaen*, Vol 1, pp 220-231.
- Devendra, C. (2006), 'Challenges and opportunities for research and development of small ruminants in Asia', *Proceedings of the X11 Asian-Australasian Animal Science Congress, 18-22 September, Busan*, pp 1-14.
- Devendra, C. (2007), 'Perspectives on animal production systems in Asia', *Livestock Science*, Vol 106, No 1, pp 1-18.
- Devendra, C., and Chantalakhana, C. (2002), 'Animals, poor people and food insecurity: opportunities for improved livelihoods through efficient natural resource management', *Outlook on Agriculture*, Vol 31, No 3, pp 161-175.
- Devendra, C., Sevilla, C., and Pezo, D. (2001), 'Food-feed systems in Asia', *Asian-Australasian Journal of Animal Science*, Vol 14, No 5, pp 733-745.
- Devendra, C., and Thomas, D. (2002), 'Crop-animal interactions in mixed farming systems in Asia', *Agricultural Systems*, Vol 71, Nos 1-2, pp 27-40.
- Devendra, C., Thomas, D., Jabbar, M. A., and Kudo, H. (1997), *Improvement of Livestock Production in Crop-Animal Systems in the Rainfed Agro-ecological Zones of South East Asia*, International Livestock Research Institute, Nairobi.
- Devendra, C., Thomas, D., Jabbar, M. A., and Zerbin, E. (2000), *Improvement of Livestock Production in Crop-Animal Systems in Agro-ecological Zones of South Asia*, ILRI, Nairobi.
- Fan, S., and Chan-Kang, C. (2003), 'Is small beautiful? Farm size, productivity and poverty in Asian agriculture', plenary paper, *25th International Conference of Agricultural Economists, 17 July, Durban* (mimeo).
- Fan, S., and Chan-Kang, C. (2005), *Road Development, Economic Growth, and Poverty in China*, Research Report No 138, IFPRI, Washington, DC, pp vii-viii.
- Fan, S., and Hazel, P. (2000), 'Should developing countries invest more in less-favored lands? An empirical analysis of rural India', *Economic and Political Weekly*, Vol 35, No 17, pp 1455-1564.
- Fan, S., Hazell, P., and Thorat, S. (2000), 'Targeting public investments by agroecological zone to achieve growth and poverty alleviation goals in rural India', *Food Policy*, Vol 20, No 4, pp 411-428.
- Fan, S., Zhang, L., and Zhang, X. (2000), 'Growth and poverty in rural China: the role of public investments', *Environment and Production Technology Division Discussion Paper No 66*, International Food Policy Research Institute, Washington, DC.
- FAO - Food and Agriculture Organization (1998), 'Sustainable agricultural production. Implications of international agricultural research', *FAO Research and Technology Paper No 4*, FAO, Rome.
- FAO (2001), Supplement to the Report of the 1990 World Census of Agriculture, FAO, Rome.
- FAO (2004), World Census of Agriculture, 1980, 1990 and 2000 Rounds, FAO Statistics Division, <http://www.fao.org/es/ess/census/wcares/default.asp>, accessed June 2005.
- FAO (2005), *World Census on Agriculture*, FAO, Rome, Website: <http://www.fao.org/es/ess/census/wcares/default/asap>.
- Hodges, J. (2005), 'Cheap food and feeding the world sustainably', *Livestock Production Science*, Vol 92, pp 1-16.
- Human Development Report (2001), *Human Development Report*, Oxford University Press, New York.
- IFAD (2001), *Rural Poverty Report 2001. The Challenge for Ending Rural Poverty*, Oxford University Press, New York.
- Lipton, M. (2005), 'The family farm in a globalizing world', *2020 Discussion Paper No 40*, IFPRI, Washington, DC.
- Livestock in Development (1999), *Livestock in Poverty-Focused Development*, Anthony Rowe Ltd, Chippenham.
- MEA - Millennium Ecosystem Assessment (2005), 'Current state and trends', in Hassan, R., Scholes, R., and Ash, N., eds, *Ecosystem and Human Well-Being*, Vol 1, pp 133-134.
- Meinzen-Dick, R., Adaro, M., Haddad, L., and Hazell, P. (2004), *Science and Poverty: An Interdisciplinary Assessment of the Impact of Agricultural Research*, IFPRI Food Policy Report, Washington, DC.
- Nagayets, O. (2005), 'Small farms: current status and key trends', *Proceedings of the Future of Small Farms*, International Food Policy Research Institute, Washington, DC, pp 355-356.
- Narayanan, S., and Gulati, A. (2002), 'Globalisation and the smallholders: a review of issues, approaches and implications', *Discussion Paper No 50*, Markets and Structural Studies Division, IFPRI, Washington, DC.
- Pretty, J. (2003), 'Social capital and collective management of resources', *Science*, Vol 302, pp 1912-1915.
- Singh, P. (2004), 'Agricultural policy: vision 2020', *Background Paper for Vision 2020*, Planning Commission, Indian Council for Agricultural Research, New Delhi (mimeograph).
- Steinfeld, H. (1998), 'Livestock production in the Asia and Pacific region: current status, issues and trends', *World Animal Review* (FAO), Vol 90, pp 14-21.
- TAC - Technical Advisory Committee (1992), *Review of CGIAR Priorities and Strategies, Part 1*, TAC Secretariat, FAO, Rome.
- Thornton, P. K., Kushka, R. L. et al (2002), 'Mapping poverty and livestock in the developing world' (mimeo), ILRI, Nairobi.
- UN - United Nations (2001), *Road Map Towards the Implementation of the United Nations Millennium Declaration*, Document A/56/326, UN, New York.
- von Braun, J. (2005), 'Small scale farmers in a liberalised trade environment', in Huvio, T., Kola, J., and Lundstom, J., eds, *Small Scale Farmers in a Liberalised Trade Environment*, Dept of Economics and Management Publication No 38, Agricultural Policy, University of Helsinki, Helsinki, Website: < <http://honeybee.helsinki.fi/mmtal/abs/Puml38.pdf> >.
- Wapenham, W. A. (1979), 'The big problem of the small farmer', *ILACO Symposium, Arnhem, Netherlands*, pp 29-51.
- World Bank (2003), 'Reaching the poor. A renewal strategy for rural development', World Bank, Washington, DC (mimeo).