



- Review -

Rainfed Areas and Animal Agriculture in Asia: The Wanting Agenda for Transforming Productivity Growth and Rural Poverty

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ABSTRACT : The importance of rainfed areas and animal agriculture on productivity enhancement and food security for economic rural growth in Asia is discussed in the context of opportunities for increasing potential contribution from them. The extent of the rainfed area of about 223 million hectares and the biophysical attributes are described. They have been variously referred to *inter alia* as fragile, marginal, dry, waste, problem, threatened, range, less favoured, low potential lands, forests and woodlands, including lowlands and uplands. Of these, the terms less favoured areas (LFAs), and low or high potential are quite widely used. The LFAs are characterised by four key features: i) very variable biophysical elements, notably poor soil quality, rainfall, length of growing season and dry periods, ii) extreme poverty and very poor people who continuously face hunger and vulnerability, iii) presence of large populations of ruminant animals (buffaloes, cattle, goats and sheep), and iv) have had minimum development attention and an unfinished wanting agenda. The rainfed humid/sub-humid areas found mainly in South East Asia (99 million ha), and arid/semi-arid tropical systems found in South Asia (116 million ha) are priority agro-ecological zones (AEZs). In India for example, the ecosystem occupies 68% of the total cultivated area and supports 40% of the human and 65% of the livestock populations. The area also produces 4% of food requirements. The biophysical and typical household characteristics, agricultural diversification, patterns of mixed farming and cropping systems are also described. Concerning animals, their role and economic importance, relevance of ownership, nomadic movements, and more importantly their potential value as the entry point for the development of LFAs is discussed. Two examples of demonstrated success concern increasing buffalo production for milk and their expanded use in semi-arid AEZs in India, and the integration of cattle and goats with oil palm in Malaysia. Revitalised development of the LFAs is justified by the demand for agricultural land to meet human needs e.g. housing, recreation and industrialisation; use of arable land to expand crop production to ceiling levels; increasing and very high animal densities; increased urbanisation and pressure on the use of available land; growing environmental concerns of very intensive crop production e.g. acidification and salinisation with rice cultivation; and human health risks due to expanding peri-urban poultry and pig production. The strategies for promoting productivity growth will require concerted R and D on improved use of LFAs, application of systems perspectives for technology delivery, increased investments, a policy framework and improved farmer-researcher-extension linkages. These challenges and their resolution in rainfed areas can forcefully impact on increased productivity, improved livelihoods and human welfare, and environmental sustainability in the future. (**Key Words :** Rainfed, Less favoured areas, Animal Agriculture, Diversification, Food Security, Feed Resources, Technology Application, Systems Perspectives, Farming Systems Research, Dryland Agriculture, Sustainability, Integration, Policy, Strategies, Impacts, Investments in R and D)

INTRODUCTION

Farming systems are the practices of agriculture in numerous ways in different locations and countries. The systems vary according to the type of agro-ecological zones

(AEZs), biophysical environment, extent and quality of the natural resources available, and the level of poverty with resource-poor farmers. Success in agricultural development is dependent to a very large extent on the efficiency in the use and management of the natural resources (land, crops, animals and water). In this context, increased efficiency in natural resource management (NRM), and environmental sustainability is justified by the need for improved land use

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systems and total factor productivity. The latter is dictated by three principal factors: About 43 to 88% of the human population depend on agriculture for their livelihoods, of which 12 to 93% of the people live in rainfed areas, and 26 to 84% of the arable land and 5 to 41% of the agricultural output comes from these areas. It is estimated that 70 to 90% of the ruminant livestock (buffaloes, cattle, goats and sheep) are found in the rainfed mixed farms. The justification for targeting rainfed areas for food production is urgent, and is linked to the following:

- Human-induced climate change with an anticipated harsher climate will cause push for extreme poverty and survival
- Need for efficiency in the use of available natural resources, and defining the objectives of production clearly in terms of potential outputs and profitability
- Understanding the significance and implications of soil-crop- animal interactions, and
- Ensuring that the resulting benefits are consistent with productivity enhancement, environmental integrity and sustainable development of rainfed areas.

Agriculture is a major sector in Asia, and FAO data (1996; 1997) indicates a contribution of 25 to 43% to the gross domestic product (GDP). Much of this contribution is made by the more fertile irrigated areas which are presently over used. However the rainfed areas which are of lower importance, also have potential, are currently underutilised and merit more development attention. About 43 to 88% of the human population depends on agriculture for their livelihoods, of which 12 to 93% of the people live in rainfed areas and 26 to 84% of the arable land. Some 5 to 41% of the agricultural output comes from these areas. Due to low productivity, the shares of total crop and livestock outputs coming from rainfed areas is much lower than the share of the total area under irrigation.

Livestock contribute 10 to 45% to the agricultural GDP in the developing world, and can be higher if the value of draught power is included in the calculation (Plate 1). It is one of the fastest growing sub-sectors in agriculture (World Bank, 2009). They play an important multifunctional and



Plate 1. Indigenous cattle used for preparing rainfed crop land in Surin, Thailand (C. Devendra).

socio-economic role. It is estimated that 70 to 90% of the ruminant livestock (buffaloes, cattle, goats and sheep) are found in the rainfed mixed farms. In India for example, the rainfed ecosystem occupies 68% of the total cultivated area and supports 40% of the human and 65 of the livestock population (Misra et al., 2009). The area produces 44% of food requirements and will continue to play a critical role in India's agriculture (Singh et al., 2004). In India also, there also exists a rainfed livestock network, whose main objective is to seek appropriate policy and programmes for livestock (Köhler-Rollefson and Kishore, 2010).

The region is also home to the dominance of small farm systems. Based on a land area less than two hectares, an overwhelming majority of 87% of the global 470 million small farms worldwide is found in Asia (Nagayets, 2005). Many of these small farms are models of efficient and integrated NRM, but the small farmers continue to experience deprivation, poverty, hunger and vulnerability (Devendra, 2010a). These small farms generally have higher yields per hectare than larger farms (Cornia, 1985), due to low labour and production costs. This inverse relationship weakens as agriculture becomes more capital intensive as has been found in India (Hanumanth Rao, 1975; Deolaliakr, 1981). The resilience of this relationship will depend to a very large extent on the use of improved technologies and policy support.

Concerning animal agriculture, there is increased emphasis and justification for improved production systems to accelerate the output of foods of animal origin in most countries in South East Asia. This is directly linked to the fact that current outputs of meat and milk from ruminants are relatively low, as are the levels of self-sufficiency in these products, which are exacerbated further by increasing imports at high cost. Increased costs can trigger higher commodity prices that can be associated with strong global demand. The latest OECD-FAO (2010) forecast is that average crop prices over the next 10 years will be 15-40% higher in real terms relative to 1997-2006.

This increased requirement is associated with several demand-driven factors and includes inadequate animal protein supplies; rising incomes, which encourage people to diversify their diets in a variety of meats; eggs and dairy products, including the substitution of calories in livestock for low-priced starch calories. Equally awesome is the inadequacy of animal protein supplies to meet current and projected future requirements and spiralling costs. Improved animal production and productivity enhancement is therefore urgent in direct response to the need for more animal proteins. The major opportunities and challenges need to be thoroughly addressed to the extent possible (Devendra, 2007a; 2010b).

A few countries such as China, India and Indonesia have given priority to the development of these rainfed

areas. In China for example, the north western region has given priority for the intensification of agricultural production and creation of “climate-free” agriculture in the grasslands through irrigation from underground sources. However, population pressures on these grasslands have been increasing, with resultant increased poverty rates, degradation, and dust storms (MEA, 2005).

This paper is concerned with the significance, importance and potential future contribution of rainfed areas in Asian agriculture: their relevance, different types of AEZs, extent, characteristics, patterns of rainfed farming systems, potential for transforming growth and improving rural prosperity. It also emphasises the opportunities for pro-poor R and D, integrated NRM, environmental sustainability, and need for investments.

DEFINITION OF RAINFED AREAS

Rainfed areas refer to all the lands outside of the irrigated, more favoured or high potential areas. The rainfed environment and areas have been variously referred to in several countries and in the literature as fragile, marginal, dry, waste, problem, threatened, range, less favoured, low potential lands, forests and woodlands, and include the reference to lowlands and uplands. Of these terms, *less favoured areas (LFAs)*, *low or high potential* are quite widely used, and will also be adopted in this paper. For India for example, Fan and Hazell (2000) analysed data for 65 AEZs and estimated that in 1993, 42% of the rural poor lived in low potential rainfed areas, 16% in irrigated areas, and 42% in high potential rainfed areas (Plates 2 and 3).

The value of the rainfed areas is totally dependent on rainfall. When the rains fail, the potential disaster is explosive with several resultant implications :

- More droughts and climate instability
- Failure of crop production and reduced grazing lands and feed availability
- Millions of households and people, with their camels.



Plate 2. Typical rainfed upland environment with grazing cashmere goats in extensive grazing systems in Liaoning province, China (C. Devendra).



Plate 3. Rural village in rainfed area in Mokhotlong, Eastern Lesotho (A. Devendra).

goats, sheep and cattle are forced into semi-nomadism and nomadism

- Poor people are marginalised further into extreme poverty, starvation and vulnerability, and
- Damage to the environment is inevitable.

EXTENT OF RAINFED AREAS

In Asia and the Pacific, the area under rainfed agriculture account for about 223 million hectares, which represents some 67% of the total available land (ADB,

Table 1. Human populations, food demand and land use in the priority agro-ecological zones of Asia* (ADB, 1989)

Parameters	Arid/semi-arid zones		Sub-humid zone		Humid zone		% of Asia in agro-ecological zones
	Amount/number	% of Asia	Amount/number	% of Asia	Amount/number	% of Asia	
Human populations in 2010 (10^6)	1,311.4	35.7	588.8	16.0	1,264.5	34.4	86.1
Food demand in 2020 (10^6 tGE)	358.6	33.4	175.5	16.3	383.9	35.8	85.5
Production of food crops (10^6 tGE)	230.9	31.5	123.6	16.9	262.7	35.9	84.3
Production of cash crops (10^6 tGE)	79.6	33.6	62.8	26.5	89.7	37.9	98.0
Land area (10^6 ha)	327.6	16.1	237.7	11.7	534.1	26.2	54.0
Arable land (10^6 ha)	191.9	41.5	73.0	15.8	123.4	26.7	84.0
Rain-fed arable land (10^6 ha)	126.8	38.8	55.2	16.9	86.1	26.3	82.0
Irrigated arable land (10^6 ha)	65.2	48.8	17.8	13.1	37.3	27.5	88.6

* t GE = Tones of grain equivalent. Excludes cool tropics.

Table 2. Distribution of land types by region (CGIAR/TAC, 2000)

Region	Land type (% of total land)				Rural population living in favoured lands (%)
	Favoured	Marginal	Sparse 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 N. America	7.8	22.6	65.8	3.9	24.0
Total (105 countries)	10.7	24.0	25.9	39.4	35.0

1989). Within this land area, the six countries in South Asia accounted for 52% of land area. Alexandratos (1995) has estimated that rainfed lands suitable for cropping in South Asia and currently not utilised approximates to 81 million hectares in South East Asia and 37 million hectares in South Asia.

Table 1 indicates the extent of rainfed agriculture and its importance in the different AEZs of the Asia-Pacific region (ADB, 1989). Rainfed areas in the arid/semi arid, sub-humid and humid AEZs were 38.8, 16.9 and 26.3 respectively as percentage proportion in Asia respectively. Of particular importance in the table also are the sizes of human population dependent on rainfed agriculture.

Table 2 provides information by region globally, on the extent and distribution of the different categories of rainfed areas (CGIAR/TAC, 2000). The reference in Asia to rainfed areas includes marginal/less favoured+arid lands+forests and woodlands. In South East Asia, the total rainfed area is 99 million ha and in South Asia 116 million ha. This diversity in itself emphasizes the justification for transforming the potential of rainfed areas through their concerted development and is reflected in the following facts in Table 1 and other observations:

- Emphasis in the past has been mainly in the irrigated areas through the “Green Revolution”, which are overused
- The “Green Revolution” mainly benefited the high

potential irrigated areas and the farmers therein, resulting in disparities with the low potential rainfed areas

- Available rainfed areas account for about 83.1% Z of the agricultural land area in Asia, found mainly in the arid/semi-arid zones and also sub-humid and humid zones, compared to 16.6% favored land. Marginal and arid lands alone constituted 48.5% of the total area.
- About 63% of the rural population was found in the former compared to only 37% in the favored areas
- It is significant to note that within the rainfed areas, in the lowlands and uplands, there exists 51 to 55% of the total population of cattle and small ruminants in Asia.
- Within the 86% of the total human population in Asia found in these areas, widespread poverty, vulnerability and the poorest of the poor are found here, and
- Natural resource degradation is evident, and major challenges exist for their more efficient and integrated development.

Table 3 gives information of the extent of rainfed areas in individual countries. In South East Asia the rainfed area as a proportion of total land available ranges from 63% in Indonesia. 68.5% in Malaysia to 97% in Cambodia. In South Asia, the corresponding values are from 27% in Pakistan to 84% in Nepal. Only in Pakistan and Sri Lanka does the percentage of irrigated land exceed that of the

Table 3. Extent and importance of rainfed agriculture in selected countries in Asia (ADB, 1989)

Country	Total rainfed area (10 ⁶ ha)	Rainfed area as a proportion of total arable land (%)	Rainfed production as a proportion of agricultural GDP (%)	Population dependant on agriculture (%)
East and S. E. Asia				
1. China	52.0	53.8	33.0	30.0
2. Indonesia	9.2	62.2	19.1	36.8
3. Thailand	13.8	81.6	49.9	59.4
4. Vietnam	4.4	53.8	33.0	30.0
S. Asia				
5. Bangladesh	7.7	81.6	40.5	41.5
6. Bhutan	0.07	81.0	28.9	93.0
7. India	100.0	69.5	25.7	43.2
8. Nepal	2.6	84.0	40.9	41.0

rainfed area. In absolute terms however, the largest irrigated land area of 43.8 million ha is found in India. The contributions of rainfed production, excluding Pakistan, to agricultural gross domestic product ranges from 16% in Malaysia to 61% in Myanmar. Most of the resource-poor farmers in rainfed areas are small farmers or smallholders and the landless, with very small farm sizes (Devendra, 2010a).

In Malaysia, both annual and perennial crop production is prevalent. While rice, fruit, pepper and vegetable production is important, the tree crops (oil palm, rubber and cocoa) dominate agriculture, involving both large plantations and small farmers. The tree crops occupy more than 86% of the total agricultural area and involve most of the fertile alluvial coastal plains and undulating foothills. Oil palm alone uses about 63.4% of the total agricultural area, followed by rubber. The land area is further expected to expand by about two per cent by 2010.

LAND USE SYSTEMS

Arable land available and use in the future is likely to be a major issue in the future. This is due to the increased use of land for industrial and recreational needs and also urbanisation. Of equal concern is the loss of about 5.7 million hectares of arable land annually through soil degradation, and a further 1.5 million hectares as a result of water logging, salinisation and alkanisation (FAO, 1999). Increasing food production in the future is linked to three possible ways:

- i) Increase existing arable land to include crop-animal systems
- ii) Intensifying the use of existing land, and
- iii) Expanding production in the LFAs

Of these options, it is doubtful that dramatic increases are going to be available from existing arable land. Maximum production has already been achieved and is levelling off. Intensifying existing land will give some increased production. Expanding production in the rainfed areas has great potential and clearly represents more attention.

In the face of looming climate change, land use systems especially in the semi-arid and arid AEZs will come under great pressure and are likely to be associated with the following :

- Considerable variation in the quantitative and qualitative changes in vegetative growth
- Problems in the management and use of natural resources
- Overstocking as a means to reduce economic risk
- Loss of vegetative cover

- Soil erosion
- Droughts, and
- Desertification

Targeting rainfed lands

The justification for targeting the rainfed areas in Asia is related the twin reasons of inadequate availability of arable land and the need to increase productivity from animals to match the projected human needs. Inadequacy of arable land and competing uses is associated with the following reasons:

- Demand for agricultural land to meet human needs e.g. housing, recreation and industrialisation
- Expansion of crop production to ceiling levels
- Increasing and very high animal densities
- Increased resettlement schemes and use of arable land
- Growing environmental concerns due to very intensive crop production e.g. acidification and salinisation with rice cultivation, and human health risks due to expanding and often very intensive peri-urban poultry and pig production, and
- Urbanisation

Urbanisation

Urbanisation for example, is a direct consequence of climate change, mediated through temperature extremes, droughts, and failed crop growth. The combined effect of these factors is significantly decreased agricultural productivity, increased poverty and vulnerability of the poor. With agricultural growth restricted by climate instability, and declining if not stagnant agriculture, non-farm activities and income generation are unable to drive the local economy, all of which hasten urbanisation.

In order to decrease the impact of this trend, many governments have promoted a strategy of providing infrastructure such as roads and communications, credits and improved technologies for people to use the LFAs more effectively or move out of them move out of them, with variable success. Indonesia's successful transmigration scheme to ease population pressure in Jawa is a case in point. Results over nine years showed increased income, enhanced crop yields, improved livelihoods in Sumatera and self-reliance Expansion in the use of available and potentially useful LFAs was apparent.

FARMING SYSTEMS IN RAINFED AREAS

In tandem with the types of prevailing AEZs, most of the sub-humid and humid rainfed areas are found in South East Asia. Within these, the lowlands have larger areas of arable and permanent crop land, which accounts for the greater crop production in this AEZ. By comparison, most

of the arid and semi-arid, and a significant proportion of the sub-humid zone occur in South Asia. The humid areas of South Asia are relatively small, and occur mainly in parts of India and Sri Lanka.

Against this background, the diversity of natural resources and farming systems, it is appropriate to briefly describe the major component types and characteristics of rainfed farming systems.

Using the definitions and consolidation of the classifications of the TAC (1994), the rainfed AEZ's of relevance are as follows:

- Rainfed temperate and tropical highlands - mainly the Hindu-Kush/Himalayan region
- Rainfed humid/sub-humid 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.

Of these, rainfed humid/sub-humid and rainfed arid/semi-arid tropical systems are priority AEZs. Most of the humid and sub-humid lowlands are found in South East Asia, while the lowlands of South Asia are semi-arid or arid. Within the AEZs, two broad areas are recognised: rainfed lowlands and rainfed uplands. The two areas are a continuum, with the former having greater opportunities for crop cultivation because of increased soil moisture and less fragility. The lowlands have larger areas of arable and permanent cropland, which account for the greater crop production in these areas. The characteristics of the lowlands and uplands have been reported (Devendra et al., 1997), and are briefly reiterated as follows:

Lowlands

These are characterised by slopes from 0 to 8%, and crop growth is entirely dependant on total rainfall and standing water. Rice is the dominant crop, and produces variable yields in the range 1.5-3.0 t/ha. Pulses and oil seeds are also grown. Buffalo populations are lower than in the irrigated areas, and the reverse is true of cattle. Pigs, poultry and ducks are common.

Uplands

The uplands are characterised by hilly lands and slopes of 8 to 18%. As is used in the Philippines and China (Plate 4). The environment is fragile, resource degradation is common, as also overgrazing. Both annual (cereals, legumes, roots and vegetables) and perennial crops (coconut, oil palm, rubber and fruit trees) are grown, often without integration with animals. Rice yields are in the range 0.9 to 1.6 t/ha. Lower populations of cattle, goats and sheep, but



Plate 4. Contour mixed farming involving maize and legumes in the uplands of Mindanao, Philippines (C. Devendra).

high populations of pigs and poultry are common relative to the lowlands. Shifting agriculture is common. Rural poverty is more acute in these areas.

The average annual rainfall of these AEZs is between 1,500-2,300 mm. Rice-based cropping systems are common, but also includes other annual crops and tree crops. Both ruminants and non-ruminants are reared, and the presence of both animal and crop diversity provide a variety of crop-animal interactions (Devendra and Thomas, 2002), the effects of which and on productivity, livelihoods of people and sustainable agriculture provide major opportunities for research and development activities. The overriding major constraint was the 5 to 7 months of dry periods and potential droughts.

Although tree crops are more commonly grown in the uplands, they are also as in oil palm cultivation, increasingly using up valuable arable land in lowland situations. In this context agroforestry, silvopastoral systems, and agropastoral systems are variously practiced, involving integration with ruminants (Devendra, 2012). These systems are underestimated, but are being increasingly recognised:

Agroforestry : involves the use of various tree crop options, usually woody perennials very commonly in rainfed areas

Silvopastoral systems: involve trees (e.g. coconuts, oil palm and rubber) and animals

Agropastoral systems: integrates crops, animals and trees

The extent and availability and efficiency of use of forage biomass from native herbage, introduced grasses and legumes and the tree crops, are the primary drivers of animal production potential of these systems. With oil palm for example, the total biomass available from the herbage and a variety of by-products increases the potential productivity and contribution from ruminants.

Biophysical characteristics

The following key features are characteristic of the rainfed areas:

- Involves the semi-arid/arid, sub-humid and humid AEZs
- Average growing period is 120-160 days
- Long dry seasons are common, with occasional droughts
- Land is of low quality : low fertility, nutrient-poor and has greater production risks
- Are usually farmed by very poor small farmers and the landless
- Rainfed agriculture is essentially subsistence
- Poverty, nutritional and food insecurity are very common
- Mixed farming of annual and perennial crops (millets, sorghum, oilseeds, cotton, rice and wheat) are the norm
- Crop failures occur more commonly in the semi-arid/arid areas
- Crop cultivation is dependant to a large extent on the return of manure from rearing animals (Plate 5)
- Are reservoirs of large concentrations of ruminants (cattle, goats and sheep), camels and smaller numbers of buffaloes and extensive systems.
- Land use systems are generally unsustainable, and are constrained by water and associated with inefficient management of the natural resources, and
- In the more arid areas overstocking as a means to reduce risk and environmental damage is common.



Plate 5. Woman delivering cattle manure as the main source of fertiliser for rainfed crop land in Nin Thuan province, South Vietnam (C. Devendra).

The large concentrations of ruminants in rainfed areas is reflected in about 51% of the total cattle and 55% of the total small ruminant population being found here (TAC, 1992). Similar data for India in rainfed areas indicated the presence of 49% cattle, 43% buffalo, 57% sheep, 45% goats, 28% pigs and 4% poultry (Ramachandra et al., 1997).

Essentially mixed farming or integrated systems

Asian agriculture is characterised by mixed farming activities which form the backbone of farming systems. It is typified by a variety of mixed or integrated systems in the various agro-ecological zones (AEZs), the diversity of crops

and animals, mainly small farm systems, small farmers and poor people (Devendra, 2007b). Mixed farming systems are synonymous with crop-animal systems, are varied and integrated with cropping in various ways, and are widespread in all AEZs. With the increasing need for food in the future, these systems are likely to see important growth and continue to be dominant in the Asian region.

Mixed farming involves both annual and perennial crops. However, the decreased availability of arable land in many countries and the need for more food from animals could encourage further integration of ruminants with tree crops in the upland areas. Associations of tree crops and animals are established farm practice in many developing countries. The expansion and intensification of these systems is a realistic objective, given the extent of farmer experience, the periodic collapse of world prices for plantation commodities and the projected demands for animal products in the future. New technologies to intensify production and better scientific guidelines for managing the components of silvo-pastoral systems are now available that can lead to higher farm incomes and a more protected environment (Plate 6). However, future development of these integrated systems will require policy support to encourage the introduction of ruminants and to increase their productivity.



Plate 6. Integrated oil palm and cattle (Brahman and Hereford) system in Sabah, east Malaysia. This production system is underestimated (C.Devendra).

Agricultural diversification

Agricultural diversification is a very common feature and is directly associated with three key reasons-*risks*, *seasonality* and *self-reliance*. The notion of risk and seasonality is linked closely to biophysical factors, and now increasingly to climate change effects. Many of the more experienced farmers are able to make the necessary adjustments to cope with the changing environmental factors, but will need all their skills to deal with the new challenges of climate change. These factors become more serious with decreasing quality of arable land.

Diversification involves the addition of a mix of crops or animals or other enterprises at the farm level and is

essentially targeted at seeking maximum food security. Apart from meeting the immediate needs of the household and also traditional self-sufficiency, specialisation follows in which income generation and market orientation become new driving forces. Diversification in terms of the use of the production resources sees expression in mixed farming activities in humid AEZs of South East Asia, and least in the more semi-arid and arid areas. The former involves crops and animals and possibly also aquaculture. Production diversification will be influenced by the following factors:

- Advances in R and D
- Technological application and scaling up
- Economic competitiveness
- Competitiveness, market opportunities and liberalisation
- Credit facilities
- Increased investments, and
- Policy and institutional commitment

Livelihood diversification

Livelihood diversification is an important means of

reducing risk by combining non-farm activities, usually in per-urban areas. It helps to ameliorate funds for the farming activities, increased security and stability of the farm households. One serious consequence of this trend is the increased responsibility and also farm work load for the wives and children of small farmers, as is noticeable throughout East and South East Asia. Women take on major responsibilities of decision making as well as oversee the needs of the farm over and above the household chores.

The extent of this diversification and the input of funds from non-farm activities will reflect to a very large extent the efficiency of the small farm agricultural activities in rainfed areas. Intensive subsistence production requires maximum use of unpaid family labour, and the drift of family labour to off-farm employment opportunities is a constraint in substance agriculture. Often this results in increased use of hired labour.

Typical household characteristics

Table 4 gives some indication of the household characteristics, bio-physical data, and patterns of farming systems on five rainfed locations in China, Indonesia,

Table 4. Some household attributes and biophysical characteristics in rainfed farming systems in five countries in South East and East Asia (Devendra, 2005)

Item	Vietnam	Thailand	Indonesia	Philippines	China
Household attributes					
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
% of farms managed by women	28.4	31.6	4.2	30.0	26.0
Biophysical attributes					
Location	Dong Tam, Bin Phuoc	Amphur Muang Mahasarakham	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
Farming systems					
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 (TLU's) 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 draft animals	Crop residues as feed, manure as fertilizer, use of draft animal	Crop residues as feed, manure as fertilizer	Crop residues as feed, manure as fertilizer	Crop residues as feed, manure as fertilizers, use of draft 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 = 0.2.

Table 5. Proportion of poor livestock keepers within production system by region (%) (Thornton et al., 2002)

Production system	Developing countries	Sub-Saharan and 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

Philippines, Thailand and Vietnam in the Crop-animal Systems Research Network (CASREN) project. The key features are as follows:

- The average annual rainfall was between 1,500-2,300 mm
- Rice-based cropping systems were common, but also includes 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, livelihoods of people and sustainable agriculture provide major opportunities for research and development activities.
- The overriding major constraint was the 5 to 7 months of dry periods and
- There was a 10 to 25% level of contribution by animals to total farm income (Devendra, 2005).

In the LFAs and the more difficult environments, the ownership of animals by poor people is especially significant and is characteristic of the farming systems, since it is an important means of sustaining livelihoods and survival. Table 5 presents the extent of poor livestock keepers by production system and region, and several

observations are relevant. Within these systems and within-region, South Asia and South East and East Asia accounted for a 59 to 60% proportion of total poor livestock keepers. Mixed irrigated systems were the next highest, with a 29 to 33.7% proportion. The higher number of poor livestock keepers in the mixed farming systems in rainfed areas is consistent with the higher proportion of the rural poor found in the combined marginal, arid lands, forests and woodlands .

CROPPING SYSTEMS

The cropping systems in rainfed areas are essentially traditional. The crops grown in the more lowland areas are rice, wheat, maize, sorghum, barley, chickpea, pigeon pea, groundnut, pearl millet, finger millet and cotton. The cropping patterns are influenced to a great extent by the climate and soil types. Most of the soils are of poor fertility, which with the low and erratic rainfall result in poor yields per hectare. Both mixed cropping and intercropping are used.

Table 6 gives an indication of the range and types of farming systems in different AEZs. The patterns of farming systems are diverse involving both annual and perennial crops and various species of animals.

Table 6. Types of mixed farming systems in the different agro-ecological zones in Asia

System and agro-ecological zone (AEZ)	Length and growing period (d)	Crops	Animals	Mixed farming benefits
Rainfed temperate and tropical highlands (e.g., Bhutan and Nepal)	<110	Barley, millet, potatoes, fruits, mustard	Yak, cattle, sheep	Traction, transport, manure, reduced risk, survival
Rainfed humid and sub-humid uplands (e.g., Vietnam, Philippines)	180-270	Maize, rice, wheat, root crops, plantation crops	Cattle, pigs, chicken	Traction, transport, income, manure, crop residues
Rainfed humid and sub-humid lowlands (e.g., Indonesia)	180-300	Maize, rice, wheat, root crops, sugar cane, mung bean	Buffalo, cattle, pigs, chickens, ducks	Traction, transport, income, manure, crop residues
Irrigated humid /sub-humid lowlands (e.g., Malaysia)	180-365	Maize, rice, cassava, sweet potatoes	Buffalo, cattle, pigs, chickens, ducks	Traction, transport, income, manure, crop residues
Rainfed arid and semi-arid lowlands, unirrigated (e.g., Pakistan, Thailand)	60-120	Sorghum, millet, groundnut, soya beans, pigeon pea, cotton	Camels, donkeys, cattle, goats, sheep, chickens	Traction, transport, income, manure, reduced risk, survival
Irrigated arid/semi-arid lowlands (e.g. India)	75-180	Millet, groundwater, pigeon pea, cotton	Cattle, pigs, chickens	Income, manure, reduced risk, survival

Typical cropping systems appropriate to individual AEZs are as follows:

- i) Rice monocrop (lowlands and uplands)
- ii) Wheat- maize-rice
- iii) Groundnut-rice-rice
- iv) Rice-mung bean or soyabean
- v) Rice-groundnut-soyabean = chilli
- vi) Sorghum-pigeon pea-sorghum
- vii) Finger millet-groundnut
- viii) Pearl millet-chickpea
- ix) Cassava monocrop (lowlands)
- x) Oil palm/rubber monocrop (lowlands)
- xi) Coconut monocrop (lowlands)
- xii) Sugarcane monocrop (lowlands)
- xiii) Mung bean-rice-mung bean
- xiv) Maize-rice-wheat

These cropping systems produce precious crop residues that are very important in the nutrition of ruminants. The value of the feeds produced increases with decreasing quality of grazing, type of AEZs, and soil type. The crop residues produced include straws from barley, finger millet, pearl millet, sorghum, wheat and rice, stover from maize, forage from chick pea and pigeon pea, haulms and meal from groundnuts.

ROLE AND ECONOMIC IMPORTANCE OF ANIMALS

Both ruminants (buffaloes, cattle, goats and sheep) and non-ruminants (poultry, pigs and ducks) are involved in these systems. Unfortunately, no data were available for the sizes of buffalo, cattle, goat and sheep and non-ruminant (pig and poultry) populations, but relatively large numbers of more than 75% of buffaloes and about 70% of non-ruminants are found on small farms. The buffaloes are mainly the swamp type in South East Asia, and account for about 33% of the total population of buffaloes in Asia.

The choice of one or more species is dependent on the biophysical environment, type of cropping system, the overriding influence of consumer preference, market dictates, potential to generate income, contribution to crop cultivation and livelihoods. Much will depend on the extent of the functional contribution of animals. Mixed farming provides a range of products, and enables farmers to diversify risk from a single commodity. The subsistence and traditional pattern of farming is such that draught power from animals is extremely important and much of the land preparation, cultivation and transportation are done by buffaloes, cattle, camels and donkeys.

Animals occupy an important economic and ecological niche in agriculture. They play a multifunctional role with

varied contributions to farming systems and human welfare. It is relevant to keep in perspective the following:

- i) Livestock constitutes about 30% of the agricultural gross domestic product (GDP) in the developing world, and about 40% of the global GDP, and is one of the fastest growing sub-sectors in agriculture (World Bank, 2009).
- ii) About 2.6 billion farmers produce the majority of food as well as all other products and services in agriculture throughout the world on small farms with less than two hectares. More than 70% of people suffering from hunger live in rural areas (IAASTD, 2008).
- iii) The significantly decreased interest and investments in agriculture, together with a lagging livestock sub-sector provides major opportunities to the owners and producers of livestock to intensify productivity in most parts of the developing world.

Ownership of animals

The ownership of animals enables many functions and the contributions are numerous. Their multifunctional role provides a variety of benefits:

- Diversification in the use of production resources and reduction of socio-economic risks
- Promotion of linkages between system components (land, crops and water)
- Generation of value-added products (e.g. 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 recycling (dung and urine)
- Contribution to sustainable agriculture, and environmental protection
- Prestige, social and recreational values; and
- Development of stable farm households

Relevance of ownership

Ownership of animals is closely associated with food security. This relates to three main socio-economic strategies and benefits (Devendra and Chantalakhana, 2002; Devendra, 2010a):

Short term current savings : this is achieved through the sale of especially small animals (eg. goats, sheep, chickens, ducks and rabbits) to meet immediate and unforeseen household needs, including food

Medium term savings : this serves as reserves to meet cash for childrens' education, and medical and farm needs (eg. buffaloes and cattle)

Long term savings : these acts as an insurance against crop failure, and sale of animals in the event of droughts, famines floods and the like (e.g. buffaloes and cattle).

The relevance of the ownership is especially pronounced in the less-favored more fragile semi-arid and arid AEZs. In these areas, climatic conditions, especially of very low rainfall and very high temperatures are extreme and the ownership of animals enables survival of very poor people, associated with which is food security. Examples of such environments are Baluchistan and North West Frontier Province in Pakistan, Rajasthan in India, and to a lesser extent north east Thailand, and the eastern islands of Indonesia. In these situations, the value of ownership of animals and their contributions increases with decreasing quality of the environment.

In India, it is instructive to note that the pattern of ownership of buffaloes and cattle in relation to size of land holdings. The landless, marginal (>1 ha) and small farmers (1-2 ha) owned 2.8, 36.1 and 21.7% of the buffaloes and 2.1, 47, 1 and 24.0% of the cattle respectively. These three groups together owned 60.6% of the buffalo and 73.5% of the cattle populations (Government of India, 1997). These same groups are also the poorest of the poor, but continue to provide a substantial proportion of milk through mainly informal marketing systems. The larger farmers will continue to flourish with scope for expansion of the operations due mainly to access to credit.

Ruminant production systems

These systems have been described and readers are encouraged to look at the main reference for the details (Devendra, 2007a). Four categories are identifiable:

- Rural landless systems
- Extensive systems
- Systems combining arable cropping (tethering, communal and arable grazing systems, and cut-and-carry feeding); and
- Systems integrated with tree cropping

Three observations are relevant about these systems:

Humid areas : For the sub-humid and humid tropics as in most parts of South East Asia such as Malaysia and the Philippines and the Mekong countries, there is underutilisation of plentiful and various types of feeds. This implies considerable opportunities for increased carrying capacities, expanding animal numbers, conservation of surpluses, and commercial production of feeds. In these circumstances, more intensive production systems are apparent involving the last two systems. The use of oil palm by-product feeds is an example of this.

Semi-arid and arid regions : By comparison, in the more difficult semi-arid and arid regions of South Asia,

there are consistent feed deficits, under-nutrition and reduced productivity from animals. The search for feeds is thus inevitable, which in turn has led to the evolution of migratory systems, mainly nomadism, transhumance and commercial systems (Plate 8).

Feed insecurity is a major constraint

Inadequate feeds is possibly the single most constraint to production especially the semi- arid and arid AEZs, mainly in South Asia where there are consistent feed deficits, under-nutrition and reduced productivity from animals. An understanding of feed balance sheets have is therefore critical to assess availability and requirements for India and Pakistan, where chronic deficits are common such as in India (Mudgal and Pradhan, 1988; Raghavan, 1995; Ramachandra et al., 2007) and Nepal (Shrestha and Pradhan, 1995). In a recent assessment of the situation in India for example, Ramachandra et al. (2007) assessed the feed resource situation in six AEZs between 2011-2020 using secondary data and gross assumptions and concluded that there was a 10-11, 35-45 and 33-35% inadequacy of dry matter, concentrate and green fodder availability respectively to meet the requirements. By comparison in the more humid AEZ of South East Asia, there are opportunities for increased carrying capacities, expanding animal numbers, conservation of surpluses, and commercial production of feeds.

Future of animal production systems

The prevailing production systems are unlikely to change in the foreseeable future (Mahadevan and Devendra, 1986; Devendra, 1989), however, there will be increasing intensification and a shift especially from extensive to systems combining arable cropping, induced by population growth and increased demand for foods of animal origin. The principal aim should therefore be improved feeding and nutrition, and maximum use of the available feed resources, notably crop residues and low quality roughages, and various leguminous forages as supplements (Plate 7).



Plate 7. Angora goat for mohair production in Clarens, South Africa (C. Devendra).

ANIMAL MOVEMENTS

Significance of nomadic and transhumant systems

In the semi-arid and arid regions where low rainfall and very high temperatures are the norm, nomadism and transhumance are intimately linked to the social life of the people. For the landless and the very poor farmers, these systems are important traditional survival strategies that have been developed by the people to cope with the seasonal changes through sheer resilience. Three key features are noteworthy:

Herd diversification : different species with different grazing habits and feed preferences e.g. goats, reduce the probability of total loss of all animals

Loaning animals and sharing herds : this enables spreading risks with other sin another area should there be a drought. Also, social contacts are strengthened.

Movement of herds : this is an obvious strategy for survival and includes a variety of traditional migrations: seasonal, short distance or long distance

Transhumance : is semi-nomadism which while is migratory, also involves some shifting arable cultivation or sedentary system in villages or oases in rainfed areas.

These migratory systems are yearly nomadic migrations of people with their cattle, goats, sheep, camels and donkeys in search of water and forage (Plate 8). The systems represent highly rational adaptations of human life to very severe adverse environment and climate change. Many such transhumance routes exist, and with the herds passing through, water supplies and plant cover are often used up well before the end of the long dry season. With the environment becoming drier by the year and concentrations of livestock continuing to grow, the shortfall especially of feeds and water is turning into a serious problem for the people.

In Rajasthan in India for example, large flocks of



Plate 8. Movement of nomads and transhumants with their flock of goats and sheep in search of feed and water during summer in Rajasthan, India (C. Devendra).

between 2,000-3,000 goats and sheep each are involved in the migration. These start in Gurg in Madya Pradesh and proceed to Jaipur over distances of over 1,800 km. Marwadi goats and Marwadi and Jaisalmeri sheep are usually involved. During the height of summer and very high temperatures (30-40°C), these result in 4-6 months of animal movement of between 10-15 km/d, motivated by the search for grazing as well as wage labour opportunities.

These systems are essentially extensive, with the difference that overwhelming numbers of goats usually with sheep are constantly on the move in search of feed and water. Both these systems are practiced by the shepherds and represent highly rational adaptations of human life to a severe and adverse environment (Devendra, 2007c), and is a natural response to traditional livelihood under extreme limitations in a stressful environment. The systems are particularly common in the semi-arid and arid areas of north western Pakistan and North India, where annual chronic shortages of feed and water shortages occur.

In the Indian sub-continent, it is estimated that between 30 and 40% of the total small ruminant population is on the move annually .These movements are spectacular, are a way of life, and involve whole households along well defined routes with several men accompanying the large flocks. Kids are often placed in baskets and are carried by camels along with kitchen utensils. With the onset of the rains and increased feed availability, grazing becomes more localised. The sheep are often shorn on the way and the wool sold at about US\$ 0.50-0.70/kg. Additionally, the animals are also used for folding (Plate 9) the practice of fertilising crop land with dung and urine at a cost of about US\$ 1,60-2.00/night , or 1 US\$ 1 per 100 animals or 60-8 kg of grain in return (Devendra, 1999).

Quite often signs of environmental degradation are apparent in areas around sources of drinking water, which are extremely localised. Streams and ponds are quickly drained after the rains, leaving livestock and people alike to rely on a variety of specialised man-made water sources the most widely used are bore holes, either man made of mechanically created.

ANIMALS AS THE ENTRY POINT FOR DEVELOPMENT

Potential development goals

The foregoing discussion on the role and economic importance of animals clearly points to the fact that animals multifunctional contributions of animals is potentially most valuable especially in the low potential areas. It is important therefore to maximise their ownership and multifunctional contribution productivity to the extent possible form the LFAs in animal agriculture. The justification to do so is

associated with the following benefits:

- Alleviate poverty, hunger and vulnerability
- Opportunity to address inadequate current and future supplies of animal proteins from the LFAs
- Accelerate production to the extent possible in improved production systems
- Seize the opportunity to apply yield enhancing improved technologies
- Demonstrate effectiveness of participatory systems methodologies and value of farmer -researcher-extension linkages, and
- Demonstrate the development of sustainable agriculture

Justification for the development of rainfed areas

The justification for targeting the rainfed areas in Asia, and use animals as the entry point for development is related to the twin reasons of inadequate availability of arable land and the need to increase productivity from animals to match the projected human needs. Inadequacy of arable land is associated with the following reasons:

- Demand for agricultural land to meet human needs e.g. housing, recreation and industrialisation
- Expansion of crop production to ceiling levels
- Increasing and very high animal densities
- Increased urbanisation and use of arable land, and
- Growing environmental concerns due to very intensive crop production e.g. acidification and salinisation with rice cultivation, and human health risks due to expanding peri-urban poultry and pig production.

The lowland rainfed areas especially those immediately adjacent to the irrigated zones are potentially very important and often high potential areas. These are the rainfed areas that have been bypassed by the 'Green Revolution' and had very limited access to the many policy issues and resource inputs of national governments. Official support is now necessary to give greater emphasis to these regions, similar to that of the irrigated areas. With improved technological interventions, increased resource use, and opportunities for improved NRM and animal production

these areas can produce more food in the future.

A few countries such as China, India and Indonesia have given priority to the development of these rainfed areas. In China for example, the northwestern region are given priority for the intensification of agricultural production and creation of 'climate-free' agriculture in the grasslands through irrigation from underground sources. However, population pressures on these grasslands have been increasing, with resultant increased poverty rates, degradation, and dust storms (MEA, 2005).

Expanding land use systems

Evidence for the important and direct role of ruminants in the expansion and use of rainfed land use is reflected in the two case studies, one each from India and Malaysia:

i) India

Associated with the ownership of buffaloes and cattle according to land holdings, it is interesting to note the distribution of buffaloes across AEZs. Table 7 presents related data also from India. While the irrigated AEZs are the traditional environments of the species, there is clear evidence that buffaloes are also expanding into mainly rainfed AEZs. Over a 25 period between 1982-1997, Table 7 indicates that the buffalo population growth rate was highest in the arid area (Government of India, 1997). The combined population growth rate of 5.2% per year for the arid and rainfed areas is over two times that of buffaloes in the irrigated areas.

Concerning Table 7, a few observations are relevant:

- Buffalo populations are clearly expanding beyond the traditional irrigated areas into the more difficult and less favoured rainfed environments
- This trend also suggests wider adaptive powers of buffaloes in the semi-arid and arid AEZs.
- The largest ownership of buffaloes by the higher proportion of landless, marginal and small farmers clearly emphasises the value of the species to the poorest of the poor and the most vulnerable
- Associated with above, the benefits to enhancing nutritional and food security is enormous, and,

Table 7. Distribution of buffaloes across agro-ecological zones in India (1972-1997) (Adapted from Govt. of India, 1997)

Agro-ecological zone (AEZ)	Area share (%)	Share in buffalo numbers (%)		Annual growth rate (1982-1997, %)
		1972	1997	
Arid	8.3	2.5	4.7	3.8
Rainfed	51.2	43.9	43.5	1.7
Hills and mountains	3.4	2.1	1.1	1.2
Coastal	7.9	8.2	1.1	0.8
Irrigated	15.2	38.4	41.9	1.9
Total	86.2	98.2	99.9	-

NB. The data excludes Jammu and Kashmir.

- The trends underline the importance of targeting development initiatives that can focus on buffaloes and cattle in appropriate rainfed environments with potential impacts on improved livelihoods of the poorest of the poor.

ii) Malaysia

The potential importance and impacts of integrated oil palm-ruminant systems have recently been reviewed (Devendra, 2009). In this context it is important to highlight the fact that integration with ruminants in oil palm areas is slowly expanding to take advantage of the many economic benefits and impacts. Currently the only about 3% of the 4.7 million hectares of land under oil palm is used for integration, but this is expected to increase further with increasing awareness and policy support from the government (Plate 9). The integration model with oil palm



Plate 9. Flock of goats and sheep “folded” at night during nomadic movement in Andhra Pradesh, India (C. Devendra).

offers extension of the principles involved with other tree crops like coconuts in the Philippines, Sri Lanka and South Asia, rubber in Indonesia, and citrus in Thailand and Vietnam, and elsewhere in Africa, Latin America and the Caribbean (Plate 7).

The potential production options within oil palm plantations are as follows:

- Breeding ruminants (buffaloes, cattle, goats and sheep) for production systems
 - Growing ruminants for meat production
 - Zero grazing systems (beeflots, goats and sheep)
 - Rearing ruminants to use the available oil palm by-products
 - Rearing ruminants for grazing and controlling weeds
 - Rearing ruminants for draught and haulage operations
 - An entry point for development of integrated NRM and sustainable production systems
 - Value addition and total productivity returns
 - A hedge for possible reduction in the price of crude palm oil

The economic benefits due to positive crop- animal- soil interactions based on a review of the existing information

gave the following results with reference to the use of cattle:

- Increased animal production and income
This arises from increased productivity and meat offtakes
- Increased yield of FFB and income
By about 30% with measures of between 0.49-3.52 mt/ha/yr
- Savings in weeding costs
By about 47-60%, equivalent to 21-62 RM/ha/yr
- Internal rate of return

The IRR of cattle under integration was 19% based on actual field data. Several theoretical calculations approximate to this value.

Increasing income generation and alleviation of poverty and food insecurity

An important approach to stimulate increased income generation is through the concerted application of yield-enhancing technologies. The justification for this is linked to the availability on many appropriate technologies, the majority have not been widely applied on- farm.

One example of this approach is the successful crop-animal systems research network (CASREN) project which was needs-based and matched appropriate impact-oriented R and D interventions. The rationale for this project is linked to high probability to improve crop-animal systems to enhance food production, food security and improved livelihoods of the poor in South East Asia. Multidisciplinary and systems-oriented R and D and challenges for integrated natural resource management (NRM) were addressed through the collaborative efforts of five national agricultural research systems (NARS) in Vietnam, Thailand, Indonesia, Philippines and China.

Several interventions, mainly nutritional, were applied appropriate to the needs of individual country locations with considerable success. The emphasis on nutrition recognises that careful and concerted attention to this factor alone can significantly increase the contribution from animals (Devendra and Leng, 2011). The results from several on-farm trials comparing farmers’ practices and improved nutritional interventions. Among the options tested are: the use of multi-nutrient block licks (MNBL), concentrates formulated from local feed resources, cassava hay as a substitute of commercial concentrates, and cassava peelings to complement grazing. All options resulted in significant improvements in the biological and economical performance, compared to the systems practiced by farmers.

STRATEGIES FOR INCREASING PRODUCTIVITY GROWTH

Several important strategies need to be pursued for

increasing productivity growth in the ruminant sector in tandem with the need to increase food from animals in the future. The strategies and opportunities relate directly to overcoming the constraints, the use of animals as an entry point for development, and the application of improved yield-enhancing technologies. There already exist a number of proven and potentially important productivity-enhancing technologies the replication of which can significantly increase productivity in animals. These include *inter alia*:

- i) Three-strata forage system (Indonesia)
- ii) Food-feed inter-cropping (Philippines, Thailand, India)
- iii) Integration of ruminants with tree crops (Malaysia, Philippines, Indonesia)
- iv) Effective utilisation of crop by-products and non-conventional feed resources (Most countries)
- v) Strategic supplementation (Most countries)
- vi) Rice-vegetable-ducks-fish integration (Indonesia, Philippines, Vietnam)
- vii) Sloping agriculture land technology (India, Nepal, Philippines), and
- viii) Processed cereal straw-based complete diets .

Systems perspectives and interdisciplinary R and D

The vigorous agenda for strategic and sustainable animal production in the LFAs in the future will require an increased commitment to interdisciplinary research and farming systems perspectives that can focus on whole-farm situations and priority AEZs. Considering the complexities of small farm systems, heterogeneity of the biophysical environment, and the various types of mixed farming, systems perspectives are therefore of paramount importance in improving the contribution of these farms, and becomes even more compelling with the threats and effects of climate change.

The methodology for systems research is distinct and follows several sequential steps: i) Site selection ii) Site description and characterisation (Diagnosis) iii) Planning of on-farm research iv) On-farm testing and validation of alternatives v) Dissemination of results vi) Impact assessment.

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

- Commitment to interdisciplinary systems approaches
- Formulation of research programmes that have community-based participation to set a common agenda and create ownership. It should involve both production and post-production systems
- Programmes that are needs-led, have institutional and structural commitment
- Establishment of effective community-based participatory planning, inter-institutional coordination

and collaboration, research management, dissemination of information, resolution of feedback issues

- Long term commitment to achieving impacts, and,
- Training in agricultural systems and systems methodologies at various levels

R AND D OF RAINFED AREAS

The justification for targeting the rainfed areas, together with the decreasing availability of arable land for farming, and increasing use due to human population increase is serious. This is further reflected in the projected decrease from between 0.17 and 1.0 ha/person in 1988/90 to 0.05 and 0.30 ha/person by 2010 (FAO, 1998). In China for example, the available arable land has decreased from 130.04 million hectares in 1996 to 130.03 million hectares in 2005. Associated with this, *per capita* arable land has fallen below 0.094 ha in 2004 (Qiu et al., 2008). Given the fragility of LFAs, the efficiency of NRM will require innovative strategies for improved soil fertility to enhance crop cultivation, coping with low rainfall, water harvesting and conservation, use of traditional ecosystem practices, and improved animal production systems that together can benefit the livelihoods of poor farmers.

An important aspect of R and D concerns the tremendous variability in the AEZs within and between - countries such as in Asia. The biophysical environment is therefore very complex, and needs - based and problem - solving R and D must therefore be adapted to fit in with the local conditions to have any tangible impact. Accelerated R and D can overcome the major constraints to agricultural production in rainfed areas. The key areas for such attention are community-based integrated natural resource management, technology delivery, and market -oriented production systems.

Such R and D perspectives will necessarily tap on the excellence of scientific principles that have already been established, as well as use of the more appropriate technologies from the developed countries. However support for, and investments in, international agricultural research in the developed countries has significantly been reduced, and will in fact probably taper off in the long term.

In the light of waning agriculture, much of the R and D initiatives will have to be generated locally and of direct relevance to the situation. Many of the stronger national agricultural research systems (NARS) like China, India, Japan and Korea are already ahead with this need. With rice or broiler production for example, these countries are a potential source of new technologies which are of much use to the weaker NARS like the Mekong countries. Adaptive research is the priority to stimulate progress in most countries. The approaches and pathways for such efforts are

part and parcel of self-reliance in Asia.

The R and D agenda must necessarily be pro-poor and specifically target the LFAs. More importantly, it must also target the more densely populated areas populated by very poor people. This approach ensures that there will be maximum impact of the R and D activities on a greater pool of poor beneficiaries in the LFAs.

Effects of climate change

An additional area of much looming concern is that of coping with the effects and climate change impacts.

A framework of national strategies for adapting to climate change and mitigation is required within which research will need to address climate-friendly productivity increases, and details of how the technologies developed appropriate to mixed farming conditions involving crops and animals. These advances can only come from increased investments in such research, supportive policy and application of systems methodologies. Table 8 provides details of the mitigation options that concern South Asia, where the problems in the semi-arid and arid AEZs are likely to be more severe than humid South East Asia. The information

Table 8. Additional mitigation options in agriculture in South Asia* (Adapted from ADB, 2009)

Issue and practice	Challenges	Opportunities	Co-benefits and contribution to sustainable development
Droughts			
	Minimise risks to farming systems	Risk minimising strategies	Increased adaptation
	Coping with heat stress	Sustainable dryland agriculture	Ecosystem resilience
	Adapting to heat stress	Heat tolerant technologies	Reduced vulnerability
	High mortality in animals	Reduced animal mortality	Increased self-reliance
	Resilience of Livelihood systems		
Dryland agriculture			
Heat tolerant crops and animals	Use of indigenous knowledge and traditional systems	Major opportunities in R and D	Sustainable production system
Improved water harvesting and conservation	Improved rainfed agriculture	Expanded use of rainfed areas	Improved understanding of the landless
Agronomy and feeding regimes	Alleviation of poverty	Increased food production	Environmental integrity
Nutrient management	Improved livelihoods		Increased nutritional and food security
			Cooperative development
Animal production			
Species and breeds	Heat tolerance	Identification of more adaptable breeds	Increased productivity
Adaptation	Optimum productivity	Distinctive adaptation traits	Increased sustainability
Feed resources	Survival	Integration with farming systems	Increased food and nutritional security
Heat stress		Development of integrated ruminants-tree crops systems (S. India and Sri Lanka)	Stable households
Soil nutrient management			
Landlessness			
Nomadism	Rationale	Improved understanding	Environmental protection
Transhumance	Way of life	Traditional systems	Survival
Livelihoods	Migratory patterns	Security	Increased ownership of animals
Animal ownership	Contribution by animals	Extent of contribution to poverty alleviation	
Rangeland management			
Grazing systems	Overstocking	Effective use of browse	Prevention of environmental damage
	Control of management	Improved fodder production	Improved livelihoods
		Increased meat production	

relate to type of practice, relative mitigation potential, challenges, opportunities, and co-benefits and contribution to sustainable development. Climate change threats and effects on agriculture and food security has recently been reviewed (Devendra, 2011).

More particularly and with specific reference to animal production, climate change will bring with it a number of potentially significant yield reducing impacts. Table 9 summarises the situation with reference to type of key issue (e.g., heat stress and feed resources), climate change impacts, and opportunities for R and D. The information that is presented is not exhaustive, but rather it has tried to capture in a comprehensive way the range of issues involved, priority attention and the need for more R and D investments.

INCREASED INVESTMENTS FOR R AND D

Agricultural research is one of the most economically productive investments that a government can make (Alston et al., 1998). There is no doubt that agricultural research can go a long way to reduce risks in agriculture, and address the great paucity of information in the understanding the effects of biophysical factors of temperature and rainfall on the natural resources and ecologies needs to start at the grass roots levels. The current problems of food deficits, spiralling production costs, changing consumer demands and the food crises, are exacerbated by decreasing and inadequate investments in agricultural research. The problems are made even more serious by inadequate technology availability and application, environmental issues, complex crop-animal-soil- people interactions and

Table 9. Major issues in animal production that will be affected by climate change impacts

Major issue	Potential climate change impacts	Opportunities for R and D
Heat stress	Physiology Metabolic Reduced feed intake Reduced reproduction Increased mortality Low productivity	Adaptation Feed efficiency Measures to increase intake Supplementation Improved management
Feed resources (Forages, crop residues, AIBP and NCFR)*	Reduced quantities Poorer nutritional quality More fibrous Decreased palatability	Use more heat tolerant plants Food-feed systems Use of multipurpose tree legumes Conservation Supplementation
Land use systems	Shift to dryland agriculture Droughts Water scarcity Diversification of agriculture Sustainability	Heat tolerant plants and animals Emphasis on rainfed agriculture Maximising feed intake Improved agronomic practices
Animal species and breeds	Adaptation Possible reduction in size Loss of biodiversity Migratory systems	Dynamics of nomadic and transhumant systems Ensuring choice for AEZ Understanding interactions with the environment Vulnerability and survival of the poor and his animals
GHG emissions from enteric fermentation and manure, producing global warming	Reduced crop growth and animal productivity Poor C sequestration	Improved use of grasses, legumes and agronomic practices Use of dietary nitrates to reduce CH ₄ Intensification
Integrates NRM and holistic systems*	R and D capacity	Interdisciplinary Use of systems perspectives C sequestration
Semi-arid and arid AEZs including rangelands	Reduced feeds Overstocking Environmental damage Landlessness	Control of numbers Use of multipurpose leguminous trees Improved management

* AIBP = Agro-industrial by-products; NCFR = Non-conventional feed resources; NRM = Natural resource management.

threats of climate change instability. If these are not urgently addressed through increased investments for R and D, the consequences of under-investments are serious and are associated with the following *inter alia*:

- Continuing rapid human population increase especially in China, India, Indonesia and also in other countries with potential food deficits
- Degradation of the environment and decreasing inefficiencies in NRM
- Increasing manifestation of depravation, poverty, hunger, vulnerability and receding aspirations of a better tomorrow
- Failure of NARS and their capacity to promote productivity and agricultural growth, and
- Inability to be self-reliant

These and other issues and the need for more funds, place considerable responsibility in individual NARS and call for an assessment of their own R and D capacity. Aspects that are associated with the R and D capacity include:

- Problem identification, definition and priority setting
- Capacity for more adaptive research
- Efficiency in research planning, resource allocation, implementation and monitoring
- Ability to attract funds from local and other sources
- Partnerships with the private sector
- Ability to generate productivity-enhancing technologies and impacts that are driven by the needs and priorities of the poor
- Can undertake *ex-ante* and *ex-post* evaluation of projects, and
- Contribute to increased self-reliance in R and D and promotion of regional and international linkages

The notion of more adaptive R and D and the search for increased self-reliance is important because increasingly technologies from the industrialised countries are becoming fewer, and many of the emerging issues are country-specific and will require resolution at the local level. In this context, the bigger and advanced NARS in Asia such as China, India, Japan and South Korea can play an increasingly prominent role in partnership with the more weaker NARS such as the Mekong countries. This process is already underway, but much more can be done to strengthen the partnerships as well as increase the funding agricultural R and D.

It is especially important to note that in studies in India (Fan et al., 2000) and China (Fan et al., 2000b); the returns to investments are very much higher in these areas in comparison to areas that have benefited from the Green Revolution. In the Indian context, improving agrarian prosperity and rural development focusing on the five

pillars of public investment, credit, infrastructure (roads, transport and agro-processing), stable markets and knowledge transformation of farmers have been proposed (Shankar and Maraty, 2009). Similarly, it has been reported that the estimated returns to agricultural R and D are high, and high enough to justify an even greater investment of public funds (Pardey and Beintema, 2001), as was reflected in the investments and policies on the use of high-yielding rice varieties that resulted in the success of the Green Revolution in India.

Additionally, the critical importance of adequate investments in the livestock sector is best reflected in dairy production in India. The dairy sector has been very well developed through participation predominantly by small farmers and the landless, backed by effective co-operative development. These individuals survive because of dairying, and it is estimated that about 70% of all milk produced comes from this sector (Birtal, 2008). Milk production contributes an average 27% of the household income, ranging from 53% for the landless to 19% for large farms (Shukla and Brahmanekar, 1999). Additionally, the sector integrates the elements of gender, cultural barriers, training and education and technology application and governance, and has led to effective marketing networks.

Over the period 1970-2004 the average annual values of outputs of different categories of the livestock sector indicated that the milk group contributed 64.4% of the total value. The milk group was a major determinant of growth of the outputs, recording 4.5%/yr compared to meat of 4.0%/yr and 2.8%/yr of other groups (Dastagiri, 2010). It is not surprising therefore that there has been a consistent call for well justified increased investments in the livestock sector (Misra et al., 2009; Dastagiri, 2010) which can also significantly alleviate rural poverty and improve livelihoods. More recently, the FAO (2011) has identified three types of critical investments for agricultural R and D:

i) Direct investment, especially in agricultural R and D to increase productivity and to enhance the ability of agricultural systems, especially smallholder farms to cope with climate change and resource scarcity

ii) Investments to link with the primary agriculture sector with the sources of demand, including agricultural institutions, extension services, rural roads, ports, power, storage and irrigation systems, and

iii) Non-agricultural investment to enhance the rural institutional environment and improve human well being; such investments include education particularly of women, sanitation and clean drinking water supply and health care.

POLICY REQUIREMENTS

A number of policy issues are needed to support

increased productivity and the development of sustainable animal agriculture. The issues by no means exhaustive but include *inter alia* attention to the following:

- The primary affirmative need is policy for a concerted R and D agenda for the UFAs that can maximise current potential future contribution.
 - The aspirations of the landless, small farmers and the syndrome of a poverty-adaptation-fragile lives-little hope-low life expectancy complex and vulnerability.
 - Asses 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"
 - Animal production needs to be seen in the broader context of production- post-production - consumption systems
 - Training needs for the relevance and application of systems perspectives and interdisciplinary for R and D on the complexity and heterogeneity of UFAs, NRM, and crop-soil-animal interactions
 - Integrated tree crops-ruminant systems are underestimated. Policy interventions are required to stimulate their development
 - Empowerment of women is central to enhance their effective contribution to the use of productive resources for food and nutritional security, and the stability of farm households
- Policy is required for national strategies for adapting to climate change and mitigation, and the development of climate-friendly technologies appropriate to mixed farming
- Micro-credits have been very useful to small farm systems, and it is essential that there be more access to this facility
 - Improvements to rural-urban market linkages, collection and processing centres, infrastructural and communication facilities are essential and reduced transaction costs, and
 - Attention for water conservation, water pricing, diversions from surplus to deficit areas, and establishing and restoring water management structures and institutions.

STRENGTHENING FARMER-RESEARCH-EXTENSION LINKAGES

In the past, the basic perception of extension is that it is a unified public sector service in technology transfer which is consistent with the keywords talking and persuasion. Currently, extension is viewed in numerous ways, from approaches to help farmers to increase production, to marketing arrangements. In recent years extension

orientation is being expanded to include innovative structural, funding and managerial arrangements (Rivera and Sulaiman, 2009), and additionally, to technical capacity and skills. Of particular concern are the various demands on extension personnel and their detracting. To overcome these, technology application and delivery needs to be reinforced to farmer-research-extension-linkages.

CONCLUSIONS

Good opportunities exist for the development and increased contribution from animal agriculture in the context of production to consumption systems. The rainfed areas are underestimated but are potentially important from the standpoint of the natural resources therein, presence of several million landless and very poor people, and relatively large populations of ruminants. Improved efficiency of NRM can significantly enhance their capacity in food production in the various AEZs. Major constraints including climate change exist, but there are also compelling opportunities and socio-economic benefits that involve rural communities. Small farms in the LFAs will continue to be important in the production of a high proportion of especially ruminant meats and milk, enhance the natural resource base, and also help alleviate poverty, hunger and food insecurity in the foreseeable future. Priority development of the rainfed areas is urgent in which animal production can serve as the entry point to address integrated NRM, increased food production and pro-poor initiatives. Social and effective development policies are also needed to spur agricultural development, increased productivity, and improved human welfare in the future.

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