

## Animal - Agricultural Systems In Asia: Enhanced Impacts and Rural Prosperity

Review Article

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### Abstract

Agriculture is challenged today by several major factors: diminishing arable land, resource constraints, increasing costs of inputs, and climate change. In Asian agriculture, productivity and economic transformation have promoted unprecedented rural growth, improved livelihoods and prosperity for progressive farmers, by-passing the poorer farmers and the landless. Animal-agriculture and animal production form the backbone, and focus on the two most critical concerns: food insecurity and poverty. Integrated R and D that links increased productivity with efficient NRM is an important pathway, involving about 87 % of the global 470 million small farms (< 2 ha) in Asia. Ruminants can be used as an entry point for the development of less-favored areas (LFAs). Given its primary task is to produce enough food to feed 9-10 billion people by 2050, the current circumstances are extremely daunting and challenging, especially increasing animal protein supplies.

The key strategy is to intensify and increase productivity from animal-agriculture with improved management of natural resources with an integrated research approach which includes *inter alia*:-

- A relentless search for efficiency in NRM to improve productivity (meat, milk or eggs) per animal and increased animal products per unit area without environmental degradation [1].
- Maximise productivity through sustained NRM, yield-enhancing technologies and intensification in whole production systems.
- Animal-agriculture provides a perfect platform for integration, the benefits of positive interactions, and community-based participation involving the farmer, researcher, extension staff and policy makers.
- Silvopastoral systems are badly neglected, underestimated and underutilized in Asia. The opportunities for interdisciplinary approaches linking productivity with NRM for economic gain, improved livelihoods and self-reliance are enormous.

Increasing productivity from animal-agriculture systems is urgent, and there is no room for complacency. Commitment to resolve the numerous challenge domains, provide practical solutions and self-reliance are important objectives in which vision must lead the way.

**Keywords:** Animal - Agriculture; Food Security; Rainfed; Natural Resource Management; Climate Change; Sustainability; Impacts; Investments; R and D.

### Introduction

Agricultural progress is an important determinant of economic growth and rural development. It is central for food security and rural prosperity, and is the most important user of environmental resources, including water, soils, pastures and rangelands. Animals are an integral backbone of Asian agriculture and provide

an important economic and ecological niche with multifunctional functions. However, critical shortages of animal proteins and inadequate human requirements remain, despite the livestock sub-sector being one of the fastest growing in agriculture [2]. In Asian agriculture, both productivity and economic transformation have impacted an unprecedented rate of rural growth which significantly improved livelihoods and prosperity of the more

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**Received:** April 25, 2016

**Accepted:** June 23, 2016

**Published:** June 28, 2016

**Citation:** C. Devendra (2016) Animal-Agricultural Systems In Asia: Enhanced Impacts and Rural Prosperity. *Int J Dairy Process Res.* 3(3), 47-65.

**doi:** <http://dx.doi.org/10.19070/2379-1578-1600012>

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progressive farmers, by-passing the poor farmers and the landless. Concurrently, agriculture is waning, and also neglected in comparison to support for industry and information communication technology. On a global scale, it is the second largest contributor to the agricultural economy, superseded only by large-scale staple cropping [3].

Agriculture in the Asian region has given greater emphasis to crop production, notably rice and wheat, based on high inputs, more concerted R and D, intensification and high capital investments. In comparison, animal production is of secondary importance, despite making a significant contribution to food security, alleviation of seasonal food supply, income and increase economic stability. Associated with this, and even more serious is the point that current supplies of animal proteins are inadequate, and will need to be more than doubled to meet future requirements, driven by major shifts in rising incomes, changing consumer preferences, demography, technological interventions, trade and policies. Animal products such as meat and milk are important sources of proteins especially for the elderly and children. With goats for example, an important feature about their dominance in rainfed areas of the developing world is that there is natural high population increase, and the species has ensured man's survival in the most poverty-stricken and (LFAs) across all regions [4, 5]. Interestingly, irrespective of location and quantum of milk used, more people drink goat milk than from any other species in the world, emphasizing priority for development. Overarching the numerous constraints is the environment, with its heterogeneity, complexities and numerous interactions. The scenario is fraught with uncertainties, risks, inaction, and dilemma (Figure 1).

The rural poor rely on agriculture almost exclusively for their livelihoods and it is the most important economic activity in most developing economies [6]. Thus the development of successful sustainable agriculture contributes significantly to economic well-being of the rural poor. Poverty responds more to rural economic growth than to urban growth, when interventions reach the poor directly by linking existing activities to the growth process. In India [7], have estimated that 82% of the rural poor live in rainfed

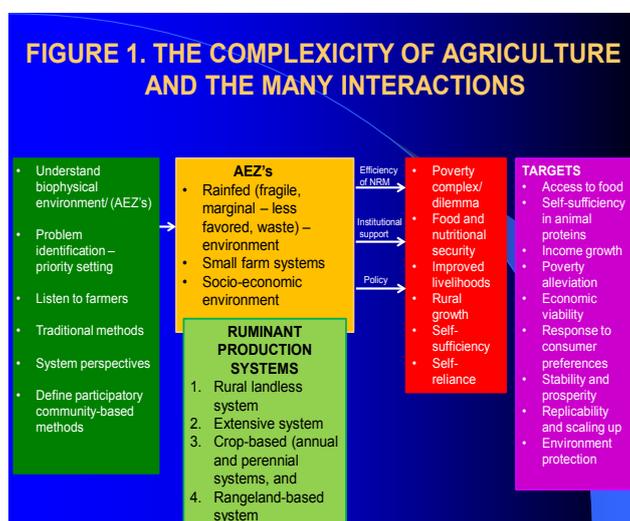
areas. Such people are highly vulnerable to climatic fluctuations. If the rains fail, the consequences are crop failure and reduction of feed availability for grazing animals. Households with camels, goats, sheep and cattle are forced into semi-nomadism and nomadism, and poor people are marginalized further into extreme poverty. Severe damage to the environment is inevitable.

The resource base (land, water and energy) is rapidly decreasing, and emphasizes the need for resource efficiency. More efficient use of natural resources is essential to reduce malnutrition and food insecurity while providing adequate food supplies to feed a burgeoning population in an environmentally sustainable way. Rising temperature, low rainfall and poor crop growth reduce the income farmers who then become more vulnerable. In China, a survey of 9810 households in the rural areas of the western region on food availability and food security [8] showed that household food security and net household income were significantly negatively correlated. Total household income was used for education, medical care and personal needs. More positively, it is interesting to note that a 1% increase in agricultural productivity to reduce poverty by 0.37%, and take 26 million people out of poverty [9].

**Emerging opportunities and challenges**

Waning agriculture is severely exacerbated today by inadequate food production systems, depleting arable land, inefficient NRM, threatening climate change, climate shocks, environmental degradation, and absence of a policy framework. Of greater concern is the paucity of scientific knowledge on many of these topics, such as climate change. The revitalization of animal-agriculture is therefore more than urgent, and a technologically driven transformation based on effective use of the natural resources and potentially important production systems can promote food security, national economic growth and environmental sustainability. A good example of this concerns silvopastoral systems which are inadequately used for integrating ruminants with tree crops. The system also enables stratification of the production systems, which provides an important opportunity to intensify natural resources [5, 10], and in particular enable breeding to increase ru-

**Figure 1. The Complexity of Agriculture and the many Interactions.**



minant numbers as well as value addition in meat or milk production. It is hoped that well informed scientists, managers of estates, and policy makers will initiate wider development of R and D for this potentially important economic opportunity.

This paper presents a comprehensive and critical assessment of the potential role and contribution of animal-agriculture in food production systems. *An overwhelming task in this context is to link increased productivity with increased efficiency of NRM, for which concerted integrated approach is necessary. The importance of integration also assumes wider whole farm systems which need to be identified with improved market participation, and value chains.* It highlights major issues that constrain potential productivity enhancement, strategies that can sustain productivity, and enhanced impacts on rural growth in the future. Brief discussions have been made on individual issues, to emphasise their relevance, the implications of the interactions, and the importance of interdisciplinarity to resolve problems and overcome constraints in integrated systems. The very complex environment justifies that high priority is given to R and D and FSR, systems perspectives and a policy framework for participation with farmers, researchers and extension personnel. Since economic growth reduces poverty, discussions include how the resource-poor and the landless can participate in economic activities for improved livelihoods and self-reliance.

## Animal production systems and the links to animal - agriculture

The terms *animal production* and *animal – agriculture* are distinctive, and have a few distinguishing features which are important to keep in perspective. Both terms have much relevance in agriculture and food systems, in which the supply of animal proteins is especially significant for food security, the poor and the malnourished. Animal production refers to the process where by specific production inputs of known quality like concentrate ingredients or diets are used to promote high and predictable responses from animals for body function and outputs like meat, milk or eggs.

The production process is very discipline - oriented. The products like meats, milk and eggs are vital as dietary proteins, as they provide one third of human requirements, and increasing current supplies poses an enormous challenges. Potentially important and cost-effective animal production systems can be expanded and become specialized. The ultimate goal is sustainable intensification in appropriate production systems that not only increase food supply, but also enable small farmers to become better stewards of the environment, enjoys good health and resilience. The successful development of such systems can then be adopted and replicated in several other similar locations. In animal production, the products (e.g. meat) and by-products (e.g. skins and offal's) from animals are the main sources of farm income. The skins have significantly high added value.

Animal-agriculture embraces the broader and overarching mixed farm environment in which it is a key sub-sector. It is the most important user of the environmental resources. More importantly, the very heterogeneous and complex nature of agriculture result in multiple interactions among the natural resources (crops, soils and water), which together with the effects of climate change, emphasise the need for integration and interdisciplinary R and D to enable improved understanding of the implications

of the process in diverse production systems. Systems framework is needed which together with FSR methodologies can facilitate careful analyses of the results, prioritization of the constraints and formulation of appropriate interventions.

Animal – agriculture is synonymous with crop-animal systems which are consistent with mixed farming. The benefits of crop-animal interactions are many due to the marked complementarity in resource use in animal-agriculture, with the inputs from one sector being supplied to others e.g. use of buffalo for draught power in rice cultivation in Bangladesh; use of cattle and goat manure for rice production in Cambodia; and in Malaysia, use of large and small ruminants for grazing on natural pasture, weed control and manure production in large oil palm estates. Due to the positive interactions, as well as diverse farming systems, a much broader range of products of economic value are generated. These include crop products e.g. rice and fresh fruit bunches in oil palm, animal products like meat and milk and total farm productivity. It is especially important to note that animal-agriculture involves the *totality of production-post-production- consumption systems.*

## Multifunctionality of animals

Animals provide a variety of functions in small farms, all of which enable to pursue farming systems. The ownership of animals very often provides them with higher income than crops to poor farmers and the landless, emphasizing the importance of the animals and their ownership. The multifunctional capacities of animals are as follows [11]:-

1. Provide a means of diversifying the use of resources , reducing socio-economic risks and a strategy for poverty reduction (Plate 1)
2. Promote linkages with components of other systems such as land, water and crops
3. Generate value-added products such as utilisation of fibrous crop residues, production of meat and milk, and providing attendant services such as draught power. and
4. Contribute to demonstrable environmentally sustainable animal – agriculture.

Such economically important products produced in the face of complex agriculture emphasise the need for instituting a systems framework or perspectives, which are backed up by good understanding of farming systems research (FSR) and holistic systems. Additionally, the holistic approach to produce various crops, animal products and by-products to the extent possible, makes understanding and use of this platform especially important with higher economic returns. With natural resources that are currently neglected and underutilized e.g. rainfed areas. non-irrigated lowlands and uplands, and silvopastoral systems, the potential value of ruminants become very important now and even more in the future. The multifunctional role of ruminants is therefore very much greater than in individual production systems, and can potentially play a much bigger role in the supply of animal proteins in the future. For these reasons, the use of the term animal-agriculture is much more relevant, and has been used throughout this paper.

## Integrated systems and intensification

**Integration:** Integration involves various components, namely

**Plate 1. Typical small farmer household in Chulidanda hilly area, Nepal .Keeping goats is a strategy against poverty. The centre part of the house is used for living, and the back portion is the kitchen. Part of the house is used to store cereal straws for winter feeding, and pen to house the goats below.**



crops, animals, land and water. Integrated systems refer to approaches that link increased productivity with improved NRM in terms of economic, social and ecological perspectives. The process is holistic, interactive, and multi-disciplinary and promotes efficiency in natural resource management (NRM). The integration of various crops and animals enable synergistic interactions, which have a greater total contribution than the sum of their individual effects [12]. Thus for example, the integration of beef cattle with oil palm results in increased FFB and palm oil, and also beef. Additionally, both ecological and economic sustainability are addressed in a mutually reinforcing manner.

Such integrated systems are especially well developed in East and South East Asia. An overview of their potential importance and relevance to small farms in Asia, and description of the distinctive characteristics has been reported [4]. The characteristic features include *inter alia*:

- Diversified and integrated use of the production resources, mainly crops and animals.
- Use of both ruminants (buffaloes, cattle, goats and sheep) and non-ruminants (chickens, ducks and pigs).
- Animals and crops play multi-purpose roles.
- The process is holistic, interactive, multi-disciplinary and promotes NRM
- Crop-animal-soil interactions are varied and have socio-economic and ecological implications.
- Low inputs use, indigenous and traditional systems, and,
- Is associated with demonstrable sustainability and sustainable production systems

**Categories of integrated systems:** Two broad categories of mixed farming systems can be identified:-

- (a) Systems combining animals and annual cropping in which there are two further sub-types:
- Systems involving non-ruminants, ponds and fish eg. Vegetables- pigs –ducks- fish systems in Vietnam, Rice – maize-vegetables- sweet potatoes – pigs – dairy cattle (China)
  - Systems involving ruminants e.g. Maize- groundnuts/soya bean – goats systems (Indonesia), Rice- finger millet- rice – goats (Nepal).
- (b) Systems combining animals and perennial cropping in which

there are again two sub-types:

- Systems involving ruminants eg. Coconuts – sheep integration (Philippines), Oil palm – cattle integration (Malaysia)
- Systems involving non-ruminants e.g. Oil palm – chickens integration (Malaysia)

**Intensification:** Intensification of animal production systems is the process of modifying production practices to increase output per animal per unit of land, and per unit of labour [13]. In ruminant production for example, the measures can be in terms of milk or meat, or biomass per unit of land. In practice, animal intensification is a response to increased demand for livestock products. The level of intensification is determined by the availability of land, feeds and the biophysical environment. The potential for productivity increases is influenced to a very large extent by NRM, which will vary from region to region, varying constraints and opportunities. In general, intensification is more prevalent in the humid and sub-humid regions than the semi-arid/ arid areas.

With mainly non-ruminants and some ruminants in peri-urban areas, the size of land is not a major constraint in intensification. At the small farm level, intensification is apparent even with such small land sizes as 0.09 ha as in China and Vietnam. The scale of operation is obviously small, but a combination of fish, pigs, kitchen waste and green leaves have enabled many years of tradition-bound systems that are models of efficiency and intensification that consistently produce household requirements for animal proteins. The largest pig and poultry units are truly industrial systems in peri-urban and urban areas. These systems depend on external inputs like germplasm, maize and micro-nutrients, with associated risks. Policy frameworks are particularly important with these systems because of intense pollution disposal of the faeces. The Landhi buffalo milk colony in Pakistan is a case in point.

## Animal - agriculture and the biophysical environment

In Asia, there are marked differences between the two AEZs: arid/semi-arid and sub-humid and humid, mainly in South Asia and South East Asia respectively, especially in regard to the resource base, agricultural production systems and feed resources (Table 1). The potential for productivity increases and NRM vary

in different countries as also varying constraints and opportunities for improvement. These overriding biophysical differences affect the resource base and both plant and animal performance and productivity in the different agro-ecological zones (AEZs). The size and diversity of the animal populations are much greater in South Asia, as also the number of indigenous breeds within-species. The goat and sheep populations are also generally higher and are concentrated in the drier AEZs such as Rajasthan. Rainfall and temperature are the two key important variables, and these together determine to a very large extent the level of productive. The lowland and uplands are a continuum (Plate 2).

## Diversity and distribution of animal populations

The animal populations in Asia are characterized by diversity, variable size of individual populations, and wide distribution across various biophysical environments. The small farms are reservoirs of a large proportion of indigenous main animal species (buffaloes, cattle, goats, sheep, chickens, pigs and ducks). These together form an important economic and ecological niche throughout Asia. Within the various and diverse AEZs, there exist relatively large individual animal populations. The animal genetic resources

**Table 1. Situational analyses in the arid/semi-arid and sub-humid/humid AEZs in Asia [42].**

Themes	Arid/semi-arid	Sub-humid/humid zone
1. Resource base	High demand for water resources	Adequate water resources
	Length of growing period 0-179 days	Length of growing period 180-270 days
	Salinity problems in soils under irrigation	
	Fragile environment with soils of low fertility	
	Land degradation associated with nomadism/ transhumance, tree removal and overgrazing	Natural resource management problems in upland areas
	Human population density low and incidence of poverty and food insecurity high	Human population density high, poverty and food insecurity high
	Adoption of improved livestock technologies variable and generally poor across countries	Adoption of improved livestock technologies variable and generally poor across countries
	Inadequate interdisciplinary research on natural resource management	Inadequate interdisciplinary research on improved natural resource management
2. Agricultural production systems	Annual and perennial crops grown under rainfed and/or irrigated conditions. Irrigation is advanced	Rice and wheat-based farming systems involving ruminants and non-ruminants, also fish in some places
	Crop-animal systems are important	Draught buffaloes and cattle, poultry and pig populations are increasing
	Relatively high populations of buffaloes and cattle	Dairy cattle and buffalo numbers marginally increasing
	Dairy buffaloes and small ruminant populations increasing, draught cattle decreasing.	Multiple cropping common, and manure is an important source of nutrients
	Development of market-oriented smallholder dairying due to co-operatives and infrastructural support	Variable integration of animals with cropping systems and intensification of crop-animal systems.
	Goats and sheep are mainly under pastoral systems interfacing with mixed farming	Market-oriented smallholder dairy less developed due to lack of marketing and infrastructure
		Animals commonly tethered or stall-fed
		Variable land areas under integrated animals – tree crop systems, mainly coconuts, oil palm and rubber and fruits. Small ruminants and cattle are usually used.
3. Feed resources	Feed deficits rampant	Tables of feed composition available in most countries.
	Poor quality feeds	Feeds are generally abundant, and deficits occur only in rainfed areas.
	Forage production in irrigated areas where dairying is developed	Good opportunities for food-feed systems, and use of leguminous forages.
	Inadequate use of AIBP <sup>1</sup> and NCFR <sup>2</sup> in urban/perurban dairy production systems	Large amounts of under-story herbage and by-products available as feeds in tree plantations
		Potential for multi-purpose trees

<sup>1</sup> AIBP-Agro-industrial by-products; <sup>2</sup> NCFR-Non-conventional feed resources

**Plate 2. Typical lowland and upland contunuum in Chulidanda hilly areas in Nepal.**

are quite sizeable, and as percentage of total world population were approximately as follows: buffaloes 96 %, cattle 34 %, goats 61 %, sheep 53 %, pigs 51 %, poultry 40 % and ducks 96 %. Within each species there is a bewildering array of breeds each with distinctive characteristics. With goats and sheep for example, there exist 143 and 233 distinctive breeds. These are widely distributed across small farms, which are the reservoirs of a large proportion of the main animal species. It is estimated that 70 to 90% of the ruminant livestock (buffaloes, cattle, goats and sheep) are found in the rained mixed farms. Native pigs and chickens are also very common and contribute significantly to food security.

Table 2 illustrates the diversity of the available species and their wide distribution in different parts of Asia. Within-species, an array of breeds exist, each with distinctive characteristics. With goats and sheep for example, there exist 143 and 233 distinctive breeds. These are widely distributed across small farms, which are the reservoirs of a large proportion of the main animal species. It is estimated that 70 to 90% of the ruminant livestock (buffaloes, cattle, goats and sheep) are found in the rained mixed farms. Native pigs and chickens are also very common and contribute significantly to food security. Table 2 illustrates the diversity of the available species and their wide distribution in different parts of Asia.

FAO data [14] indicates a contribution of 25 to 43% of the gross domestic product (GDP). Much of this contribution is from the fertile irrigated areas which are presently over used and yields are plateauing. 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. It is one of the fastest growing sub-sectors in agriculture [15]. They play an important multifunctional and socio-economic role [16]. Two key factors that affect animal performance are heat stress, feeding and nutrition. The strategy will enable the animals to recover from the stresses with high quality diets. Table 2

## Daunting challenges for production

### Pathways for food production systems

There are three optional pathways for increasing food production in the future:-

➤ Intensify and expand existing arable land areas to include

crop-animal systems;

➤ Intensify the use of existing land; and

➤ Expand production in less favoured areas (LFAs).

The first option involves improved agronomic and managerial practices, including, for example, the use of fertilizers or rice bunds to grow vegetables for households, or leguminous trees to provide forage for the animals. This option is limited in scope and is unlikely to contribute significantly to increased food supplies. Total factor productivity per unit of land or labour appears to have replaced resource expansion and input intensification as the primary driver of growth in agriculture [17]. An ideal food-feed system is one that maintains or increases the yield of the food crop, sustains soil fertility, and provides dietary nutrients for animal [18]. Currently, about 2.6 billion small farmers, living on small farms with less than two hectares, produce the majority of food, products and services in agriculture throughout the world. It is also important to note that the poor derive a higher share of their household income from livestock sources than do the wealthier in the same rural communities [19, 20]. Has reported that climate change is expected to put 49 million additional people at risk of hunger by 2020, and 132 million by 2050. The majority of these are resource-poor, and are those who have been by-passed by the Green revolution.

The projected human population growth rates are awesome, and are projected to increase by 0.7%, 1.6% and 1.4% per year up to year 2010. An immediate consequence of coping with inadequate food supplies is to resort to excessive imports at high cost, often at an increasing rate without concurrent development of alternative mitigating strategies which are feasible. Such moves are generally increasingly expensive, and call for much more emphasis on using local resources and promote self-reliance. What then are the options for animal-agriculture to overcome the main constraints?

The projected needs for more foods of animal origin in Asia are thus beset with major problems, and have a number of demand-driven consequences and challenges which need to be addressed with the objective of removing the constraints. These include *inter alia*:

- i. Stress on use of natural resources;
- ii. Emphasis on improved efficiency in feed resource use and increased and productivity per animal.
- iii. Intensification of animal production systems;

Table 2. Distribution of domestic animals by ecosystem and sub-regions in Asia [4].

Sub-region	Agro-ecosystems and animal species								
	Lowland irrigated			Lowland/upland rainfed			Semi-arid and arid		
	Buffalo/ Cattle	Goat/ Sheep	Pig/ poultry/ duck	Buffalo/ Cattle	Goat/ Sheep	Pig/ poultry/ Duck	Buffalo/ Cattle	Goat/ sheep	Pigs/ Poultry /ducks
China	***	*	***	**	***	***	*	***	*
Hindu Kush	***	*	**	**	***	*	*	—	—
South Asia	***	*	**	**	***	**	*	***	—
Mekong	***	*	***	**	**	***	**	*	—
Countries									
South East Asia	***	*	***	**	**	***	*	**	*

Notes: \* = Low concentration; \*\* = medium concentration; \*\*\* = high concentrate

- iv. Need for agricultural development to shift to rainfed areas or the LFAs
- v. Increased concentration of animals in peri-urban areas;
- vi. Increased disease risks, pollution and human health issues; and
- vii. Urbanisation-associated with increased consumption of poultry, pork, eggs, beef, goat meat and mutton.

The rapid growth in the consumption of foods of animal origin is especially spectacular in East and South East Asia where the demand has placed unprecedented pressure on NRM. The primary goal is efficient use of natural resources (land, water, crops and animals) that is consistent with productivity enhancement and environmental sustainability. When the income generation is sustained across Asia, the implications on supply value chains are enormous. The more progressive farmers will expand production, which with increased cost of feeds raise transaction costs, and increase the cost of supplies. Animal products such as meat, eggs and milk are important, concentrated and digestible sources of high quality proteins and energy, and have higher prices. Among the red meats, goat meat has a higher lean content than beef or mutton because fat tends to be more concentrated in the viscera rather than sub-cutaneous. Goat milk also has anti-allergic properties and the other is the presence of higher levels of six of the ten essential amino acids, and also monounsaturated, polyunsaturated, and medium chain triglycerides, all of which are known to benefit human health [5, 21].

## Land use for production systems

### 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 different countries as fragile, marginal, dry, waste, problem, threatened, range, less favored, low potential lands and woodlands, and include the reference to lowlands and uplands. Of these terms, *less favored areas* (LFAs), with low or high potential are quite widely used, and will also be adopted in this paper. For India for example [7], 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. 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. Goats, sheep and cattle are forced into semi-nomadism and nomadism in search of feed and water (Plate 3)
- Poor people are marginalised further into extreme poverty, starvation and vulnerability, and
- Damage to the environment is inevitable. Effective land use is an important determinant of agricultural productivity. (Plate 3 here)

Of the factors affecting productivity and the extent of supply of animal proteins, type of production system, biophysical and environmental factors, and the quantity and quality of feeds, are all influenced by the availability and quality of the land, and eventually the performance of ruminants. The last factor of feed availability and quality and land, will determine the type of production system that is appropriate. Excluding goats and camels, it is very doubtful if cattle and sheep, can withstand the very high temperatures and heat stress that are found in the arid and semi-arid regions.

Arable land for crop production and agriculture is limited. While giving priority to opportunities for development in neglected rain fed areas and less favored areas (LFAs), more emphasis need be given to high-potential areas – these are adjacent to irrigated areas with soils of relatively high moisture content. They are characterized by poor soil quality, low rainfall, short growing season with dry periods, and resource-poor farmers and peasants who experience extreme poverty, hunger and vulnerability. An important resource in LFAs is the presence of large populations of ruminants (particularly goats, sheep and camels), with smaller numbers of cattle and buffaloes generally in low productivity areas. These produce valuable dung and urine which are the main sources of fertility for the soils (Plate 4).

The factors constraining the availability of arable land include the following:-

**Plate 3. Woman farmer with her flock of goats in very extensive grazig in Andhra Pradesh in India, In such systems, meagre feeds, lopped tree leaves and available feeds provide the main sources of nourishment Dung from ruminants is the main source of fertiliser in small farms.**



**Table 3. Distribution of land types (% of total land) by region [25].**

Region	arid lands	Favoured woodlands	Marginal in favoured lands (%)	Sparsely populated	Forest and	Rural population living
Asia	16.6	30.0	18.5	34.6	37.0	
Latin America and the 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	

- 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
- Human health risks due to expanding and often very intensive peri-urban poultry and pig production, and
- Urbanisation.

An associated problem of increasing concern is fragmentation and the decreasing size of farm land. In China for example; the available arable land has decreased from 130.04 million hectares in 1996 to 103.03 million hectares in 2005. Associated with this, *per capita* arable land has fallen below 0.094 ha in 2004 [22]. 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 alkalinisation. If the process of land fragmentation continues without any consolidation, in the long term it is feasible that farmers will have to shift out of agriculture.

Given the fragility of LFAs, the efficiency of NRM will require innovative strategies for improved soil fertility to enhance crop cultivation with the minimum of resources. These include coping with low rainfall, water harvesting and conservation, use of traditional ecosystem practices, Extensive use of manure (See Plates 2 and 4), as well as improved animal production systems that together can benefit the livelihood of small farms and poor farmers [23]. The occurrence of increased human-induced climate change

with an anticipated harsher climate will push for extreme poverty and survival. Hence, there is a need for efficiency in the use of available natural resources, as well as defining the objectives of production more clearly in terms of potential outputs and profitability. In this context, listening to farmers about community knowledge, traditions and their experiences with NRM provide advantages for the success of a project [24]. Furthermore, the significance and implications of soil-crop-animal interactions need to be understood so that the resulting benefits are consistent with productivity enhancement, environmental integrity and sustainable development of rainfed areas.

More emphasis should be given to high-potential areas—these are areas adjacent to irrigated areas with soils of relatively high moisture content. They are characterized by poor soil quality, low rainfall, short growing season with dry periods and resource-poor farmers. In rice ecosystems, four categories are identifiable, but the areas immediately outside the irrigated areas has the benefit of water seepage and spill over from the irrigated areas. These areas are very useful to plant growth which of course will also produce reasonable yields.

#### Value and use of rainfed lands

The justification to shift development to the rainfed areas is therefore quite clear. Rainfall impacts directly on productivity, so when rains fail the implications are serious, including: droughts and climate instability; crop failure and reduced grazing lands and feed availability; households with camels, goats, sheep and cattle are forced into semi-nomadism and nomadism; poor people are marginalized further into extreme poverty; and damage the environment is inevitable. Without exception, rainfed areas are consider-

**Plate 4. Photo shows small amounts of dung dispersed in rainfed areas of Bin Phoc province, Vietnam for the cultivation of rice.**



ably larger than favored areas. In South East Asia, the total rainfed area is 99 million ha and in South Asia 116 million ha. In South East Asia, the rainfed area as a proportion of total land available ranges from 63% in Indonesia and 68.5% in Malaysia to 97% in Cambodia. In South Asia, the areas range from 27% in Pakistan to 84% in Nepal. Only in Pakistan and Sri Lanka does the percentage of irrigated land exceed the rainfed area. In absolute terms, however, the largest irrigated area (43.8 million ha) is in India [26]. Of particular importance is the size of human population dependent on rainfed agriculture.

#### **Distribution of rainfed lands**

Table 4 summarizes data by region on the extent and distribution of different categories of rainfed areas [25]. Rainfed agriculture is essentially subsistence agriculture where poverty, nutrition and food insecurity are common. Mixed farming of annual and perennial crops (millets, sorghum, oilseeds, cotton, rice and wheat) is the norm. Crop failures occur more commonly in semi-arid and arid areas, and crop cultivation is dependent to a large extent on the return of manure from rearing animals. On the positive side, the oil palm environment often found in rainfed areas, offers a number of useful attributes that favour ruminant production systems and enhance productivity. With regard to climate change, there is a paucity of information concerning the effects of the biophysical factors of temperature and rainfall on natural resources and ecology. Note also that there were very much more people living in unfavored compared to favored areas.

Without exception, rainfed areas are considerably larger than favored areas. In South East Asia, the total rainfed area is 99 million ha and in South Asia 116 million ha. In South East Asia, the rainfed area as a proportion of total land available ranged from 63% in Indonesia and 68.5% in Malaysia to 97% in Cambodia. In South Asia, the areas range from 27% in Pakistan to 84% in Nepal. Only in Pakistan and Sri Lanka does the percentage of irrigated land exceed the rainfed area. In absolute terms, however, the largest irrigated area (43.8 million ha) is in India [26]. Of particular importance is the size of human population dependent on rainfed agriculture. Table 4.

#### **The diversity and use of feed resources**

A comprehensive sweep and assessment of the extensive subject to feed resources across countries in Asia is important. The

analyses of important publications over the last two decades, led to the conclusion that there are a plethora of abundant complex variables which needed to be carefully discerned. Numerous FAO issues are available and include *inter alia*, bewildering variety of animal species and breeds which can be used to advantage; the potentially useful and variable types of feeds; biophysical environment and agro-ecological zones (AEZs). The relevance of feeds need to be considered in relation to availability; seasonality of production; quality of nutrient composition; use in animal production systems; optimum level in the diet; response in animals; methods of storage; wastage; conservation; accessibility to markets; economic and export potential. Understanding the significance of these various factors enabled their use to the extent possible, the potential response and productivity in animals, in terms of meat, milk, fibre and skins. Feed resources in this context are the drivers of production systems, performance and productivity [27]. On the other hand, LFAs are fragile environments, and particular attention needs to be given to available feeds that can match the requirements of animal, failing which over stocking and environmental degradation are inevitable. The more arid LFAs and the rangelands are particularly vulnerable on this issue (Plate 5).

Failure to have this basic understanding of the value of a feed, is bordering on predictable failure. Enquiries to national programs about the reasons for the low level of production and failure invariably shifted the blame to poor quality feeds, methods of feeding inadequate funding, and inability to shift resources to more holistic work at farm level. The tendency in research and development (R and D) programs was to focus mainly on discipline-based efforts, with scant shifts to community-based joint participation that apply improved technologies, holistically and are backed by systems-perspectives. More recently, the latter has been significantly enriched by education and training, which are powerful and important drivers of community-based participation and cooperative development. This trend also augurs well for significantly promoting the innovative and productive potential of dominant small farm systems in Asia.

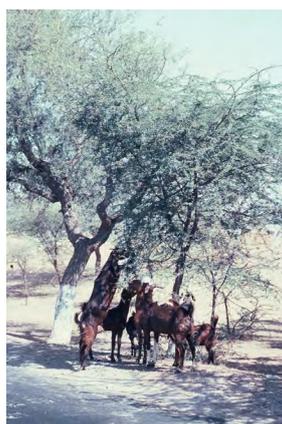
#### **Potential opportunities for food production systems in small farms**

##### **Crop-animal interactions**

Crop-animal interactions occur in animal-agriculture or mixed

Table 4. Types of crop-animal interactions in various countries in Asia [30].

Country	Interactions
China	<ul style="list-style-type: none"> <li>• Manure from dairy cattle for triticale and rice production in the Beijing municipality;</li> <li>• Manure from pigs for maize and rice production in the Hunan Province;</li> <li>• Manure from black goats for vegetable production in the Hunan Province; and</li> <li>• Buffaloes and cattle for draught in Hunan and Yunnan Provinces.</li> </ul>
India	<ul style="list-style-type: none"> <li>• Manure from small ruminant flocks folded on arable land in Gujarat and Rajasthan States</li> <li>• Sorghum residues by cattle in the Andhra Pradesh State;</li> <li>• Cattle for draught power in rice–wheat production systems; and</li> <li>• Manure from large ruminants for cropping in Uttar Pradesh State.</li> </ul>
Malaysia	<ul style="list-style-type: none"> <li>• Buffaloes and cattle are used extensively for haulage and transportation of products such as fresh fruit bunches draught in oil palm estates;</li> <li>• Animals grazing the herbage control weeds;</li> <li>• There are reduced weeding costs (16 – 40%)</li> <li>• The effective utilisation of the feeds gives valuable animal products such as meat, milk and eggs; and</li> <li>• Animals provide an entry point for the introduction of improved grasses (e.g. Guinea grass) and legumes (e.g. <i>Gliricidia</i>) for productivity enhancement in animals with attendant benefits.</li> </ul>
Nepal	<ul style="list-style-type: none"> <li>• Manure for composting from cattle and buffalo in the mid-hills region;</li> <li>• Crop residues in the Terai region for what crop product or animal feed; and</li> <li>• Cattle and buffaloes for draught power in the Terai and mid-hill regions.</li> </ul>
The Philippines	<ul style="list-style-type: none"> <li>• Small ruminants for weed control under coconut in Southern Luzon;</li> <li>• Manure from cattle feedlots for pineapple production in northern Mindanao; and</li> <li>• Ducks in rice paddies to control golden snails (rice pests in Southern Luzon).</li> </ul>
Sri Lanka	<ul style="list-style-type: none"> <li>• Buffaloes for land preparation in rice production in the wet and intermediate zones;</li> <li>• Rice straw by cattle in the irrigated dry zone; and</li> <li>• Cattle for weed control and manure application under coconuts in the intermediate zone</li> </ul>
Thailand	<ul style="list-style-type: none"> <li>• Rice straw for cattle and buffalo feed in the North-eastern Province;</li> <li>• Manure from stall-fed large ruminants for rice production in North-eastern Province; and</li> <li>• Buffaloes for draught power in rice production in Northeast Province.</li> </ul>
Vietnam	<ul style="list-style-type: none"> <li>• Buffaloes for draught power in rice production in Song Be Province;</li> <li>• Crop residues in the Song Be Province; and</li> <li>• Ducks feed on weeds in ponds fertilised by pig manure in central and North-eastern areas</li> </ul>

Plate 5. Sirohi goats browsing on *Acacia* trees in Agra, India. Left uncontrolled, goats can damage the environment.

farming situations. Agricultural production is to a very large extent a manifestation of crop-animal-soil-water interactions. The interactions are the result of system components which impact on the environment through production systems, feed availability, various activities, use of various inputs and management practices. These interactions benefit small farmers, and contribute to the sustainability of the small farms. For example, livestock provide draught power and manure for use in the cropping systems. In plantation agriculture, animals grazing the vegetation under tree crops such as coconut or oil palm reduce the costs of weeding

and of herbicides used. Table 4 gives an indication of the types of crop-animal-soil-interactions in different countries. Table 4.

#### Enhancing increased productivity from small farms

Globally, Asia has the largest proportion (87% or 625 million) small farms (< 2 ha) [28]. The key descriptors are *deprivation, subsistence, illiteracy, resilience, survival and vulnerability* [29]. More than two-thirds of the three billion rural people live on small farms where food insecurity is manifest. It is important to note that

about 2.6 billion small farmers produce about 90% of milk, 77 % of ruminant meats, and 47% of non-ruminant meats, 31% eggs and services in throughout the year. These small farms generally have higher yields per hectare than larger farms [31], due to low labour and production costs [32]. Has highlighted the enormous productive and innovative potential of small farmers. Many of these small farms are models of efficiency, and have the potential to increase current levels of productivity. Increased adoption of new yield-inducing technologies and improved agronomic practices can significantly increase productivity.

Farming systems in small farms are characterized by use of low levels of inputs; limited access to resources and services; technologies and micro credits; dependence on indigenous knowledge and traditions; production of cash crops (Plate 6) to generate income to meet household needs or to purchase of animals; low economic efficiency; low transaction costs; dependence on unpaid family labour; poor access to markets; bargaining power; and have environmental resilience. Small farmers are resource-poor; geographically isolated; continuously experience hunger, poverty; are able to adapt to hardship; survive; resist change and are averse to risk-taking [17] Plate 6.

Many of the facts pertaining to constraints to animal –agriculture in Asia have been recently reviewed (see for e.g. (i) The environment from an agricultural perspective [29]; (ii) Asian farming systems [30]; climate change [32-35]; silvopastoral systems [4, 5] supply value chain [36]; agricultural education [36] and investment [29,

36]. It is not intended therefore to repeat much of the discussions, except to highlight the key issues and readers are encouraged to use the references. The discussions that follow will focus on those issues that are considered most promising for enhanced impact, importance, and potential to spur agricultural growth, reducing poverty and food insecurity, and more particularly, the enormous pressure they place on the natural resources. In this context, the major sections include land use systems, feed resources, effective technology transfer and impacts, climate change, supply value chains and farming systems perspectives.

### Silvopastoral systems and carbon sequestration

Silvopastoral systems are underestimated and underutilized in developing countries, especially where tree plantations are abundant, such as oil palm in Indonesia, Malaysia and Colombia (Figure 8 here). While the term ‘agroforestry’ is more widely recognized, silvopastoral systems tend to be neglected or marginalized, probably because of its link with animals. Younger oil palm plantations have abundant oil palm leaves (Plate 7).

An additional advantage in this system is carbon sequestration. Carbon sequestration is an important pathway to stabilize the environment with minimum effects of climate change. Farming systems provide a non-compensated service to society by removing atmospheric carbon generated from fossil fuel combustion, feed production, land restoration, deforestation, biomass burning and drainage of wetlands. The resultant increase in the global

**Plate 6. The food-feed system is an important strategy. Photo shows farmer with cowpea - cassava system of benefit to both household consumption and feed for animals in Mahasarakam, north east Thailand, similar to rice-siratromungbean system in the Philippines.**



**Plate 7. Young oil palm plantation. Note the abundance of oil palm leaves.**



emissions of carbon is calculated at 270 Gt, and increasing at the rate of 4 billion tonnes year<sup>-1</sup>. Strategies to maximize carbon sequestration through enhanced farming practices, particularly in crop–animal systems, are thus an important priority to reduce global warming.

These pathways also respond to agricultural productivity in the multifaceted, less favoured rainfed environments. Sustainable animal agriculture requires an understanding of crop–animal interactions and integrated natural resource management (NRM), demonstrated in the development of underestimated silvopastoral systems (tree crops and ruminants). practices potentially enhance carbon sinks and soil organic matter through leguminous trees (e.g. *Leucaena*), integrated nutrient management and use of animal manure. These interventions significantly increase ecosystem services, crop and animal productivity, reduce CH<sub>4</sub> emissions and mitigate N<sub>2</sub>O emissions and ammonia volatilization. Current research and development (R and D) efforts on the characterization of forages and research on heat stress and economic animal productivity are urgently needed [37].

Despite its potential economic advantages, the system has poor adoption rates. In addition, the system promotes stratification, which provides an important opportunity to intensify natural resources [5, 34]. There are many reasons for this, including poor awareness of the potential benefits, strong resistance from the crop-oriented plantation sector, and plant production bias by crop scientists and plantation managers. Stratification provides several production options – breeding ruminants (buffaloes, cattle, goats and sheep) for production systems; growing ruminants for meat production; and zero-grazing systems (feedlots, goats and sheep). Plate 8.

### Oil palm and the land areas

Approximately 78% of the total cultivated land area in Asia (about six million hectares) is used for oil palm. Inadequate emphasis on developing this production system. Table 5 illustrates the current extent of oil palm areas in South East Asia. Out of global total 2.53 million hectares, Indonesia, his two together account for 91 % of certified sustainable palm oil. Smaller land areas with oil palm are found in Papua New Guinea. Malaysia has 4.7 million hectares of oil palm plantations, 60% of which are considered large, and the remaining 40% are in the hands of small farmers. The oil palm is often referred to as the “golden crop”.

The oil palm areas except for growth, and remain largely neglected and underutilised from the standpoint of promoting their integration with ruminants. Of the tree crops that are presently grown, the oil palm is probably the most important in economic terms. R and D of integrated ruminants and tree crop systems have been identified as a priority for future production in Asia, [38]. (Table 5)

In Malaysia, the oil palm planted area in 2015 involves 5642 million hectare, made up of 2.659, 1.544 and 1.439 million hectare in Peninsular Malaysia, Sabah and Sarawak respectively [39]. 86 % of the area had 86.1% mature palms and 13, 9 immature palms [39] % of the total area, private estates held 61 %, Federal and State agencies 23: and small farmers 16 %.

### Oil palm-ruminant's interactions

Oil palm interactions are many, and it is important that these be identified, so as to take advantage of the implications of the nature and extent of crop–animal interactions in the oil palm. These are largely positive, although there can also be negative effects such as damage to the palms when there is overstocking or when animals are integrated with young palms.

### Grazing cattle oil palm plantations

Some preliminary research has produced some important pointers, which are reflected in table 6. Native herbage in oil palm plantations is quite capable of giving live weight gain. This decreases with increasing stocking rate due to inadequate availability of feeds, On the other hand, exotic animals can give much higher live weight gains with improved pasture [40]. Table 6.

### Economic benefits of oil palm-cattle integration

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:

- (1) Increased animal production and income.  
This arises from increased productivity and meat offtake.
- (2) Increased yields of FFB and income  
The escalation is by about 30 % with measures of between 0.49 – 3.52 mt/ha/yr.

**Plate 8. The integration of Brahman cattle with oil palm plantations in Kinabalu ,Sabah, Malaysia. This rainfed production system is underutilised and underestimated despite a several economic advantages.**



Table 5. Major impacts of climate change on animal production.

Major issue	Potential climate change impacts	Opportunities for R and D
1. Heat stress	<ul style="list-style-type: none"> <li>• Physiology</li> <li>• Metabolic</li> <li>• Reduced feed intake</li> <li>• Reduced reproduction</li> <li>• Increased mortality</li> <li>• Low productivity</li> </ul>	<ul style="list-style-type: none"> <li>• Adaptation</li> <li>• Feed efficiency</li> <li>• Measures to increase intake</li> <li>• Supplementation</li> <li>• Improved management</li> <li>• Shade</li> </ul>
2. Feed resources (Forages, crop residues , AIBP and NCFR)*	<ul style="list-style-type: none"> <li>• Reduced quantities</li> <li>• Poorer nutritional quality</li> <li>• More fibrous</li> <li>• Decreased palatability</li> <li>• Reduced digestibility</li> </ul>	<ul style="list-style-type: none"> <li>• Use more heat tolerant plants</li> <li>• Food-feed systems</li> <li>• Use of multipurpose tree legumes</li> <li>• Conservation</li> </ul>
3. Land use systems	<ul style="list-style-type: none"> <li>• Shift to dry land agriculture</li> <li>• Droughts</li> <li>• Water scarcity</li> <li>• Diversification of agriculture</li> <li>• Sustainability</li> </ul>	<ul style="list-style-type: none"> <li>• Heat tolerant plants and animals</li> <li>• Development of food-feed systems</li> <li>• Emphasis on rainfed agriculture in LFAs</li> <li>• Maximising feed supply</li> </ul>
4. Animal species and breeds	<ul style="list-style-type: none"> <li>• Adaptation</li> <li>• Yield changes</li> <li>• Possible reduction in size</li> <li>• Loss of biodiversity</li> <li>• Loss of grazing land</li> <li>• Flooding in river deltas</li> <li>• Migratory systems</li> </ul>	<ul style="list-style-type: none"> <li>• Dynamics of nomadic and transhumant systems</li> <li>• Ensuring choice of AEZ</li> <li>• Understanding interactions with the environment</li> <li>• Vulnerability and survival of the poor and the ownership of animals</li> </ul>
5. GHG emissions Enteric fermentation and manure, producing global warming	<ul style="list-style-type: none"> <li>• Reduced crop growth and animal productivity</li> <li>• Poor C sequestration</li> </ul>	<ul style="list-style-type: none"> <li>• Improved use of grasses, legumes and agronomic practices</li> <li>• Use of dietary nitrates to reduce CH<sub>4</sub></li> </ul>
6. Integrated NRM and holistic systems**	<ul style="list-style-type: none"> <li>• R and D capacity</li> </ul>	<ul style="list-style-type: none"> <li>• Intensification Interdisciplinary Rand D</li> </ul>
7. Semi-arid and arid AEZs, including rangelands	<ul style="list-style-type: none"> <li>• Reduced feeds</li> <li>• Overstocking</li> <li>• Environmental damage</li> <li>• Landlessness</li> <li>• Water conservation</li> </ul>	<ul style="list-style-type: none"> <li>• Use of systems perspectives</li> <li>• C sequestration</li> <li>• Impacts</li> <li>• Control of numbers</li> <li>• Use of leguminous trees</li> <li>• Improved management</li> <li>• Water use efficiency</li> </ul>

\*AIBP- Agro-industrial by-products ; NCFR-Non-conventional feed resources

\*\* NRM- Natural resource management

### (3) Savings in weeding costs

The costs are lessened by about 47- 60 %, equivalent to 21 – 62 RM/ha/yr.

### (4) Internal Rate of Return (IRR)

The IRR of cattle under integration was 19% based on actual field data.

Such systems enable the stratification of production in national breeding programs and in situ use of crop-products.

## Adoption of improved productivity - inducing technologies

Several potentially important technologies exist for adoption, but it is not intended here to catalogue the full list. Rather, an attempt

is made to provide a list of the potentially more important and yield-inducing technologies in animal-agriculture that have been shown to be very promising but have been inadequately used on farms, and potentially valuable to Asian agriculture. Many of the results have also been extensively reviewed and are also replicable in Africa and Latin America and the Caribbean.

The expanding area under oil palm offers major opportunities to integrate ruminants and increase total factor productivity. Such systems enable good linkages between production and post-production systems, along with environmental sustainability, including carbon sequestration [34] have reported that no agricultural technology will have impact unless farmers` adopt it Unfortunately, this integrated system has been sadly neglected and underutilised by the planters despite all the beneficial scientific and economic facts. The interventions below have been listed to highlight their

Table 6. Land area under Certified sustainable palm oil [38].

Country	% ownership *
Indonesia	50
Malaysia	41
Papua New Guinea	5.8
Others	4.2
Total	100

\*Out of a total area of 2.53 million hectares

potential intensive use to increase productivity. More importantly, it is emphasised that many of the interventions below are consistently impact-oriented, and can therefore be replicated elsewhere.

- [a]. Aquatic plants (e.g. duckweed) from wastewater
- [b]. Crop-animal-fish integration [4, 27]
- [c]. Crop residues as ruminant feed [38, 41]
- [d]. Environment [42]
- [e]. FSR methods, systems and impacts: [30, 43-45]
- [f]. Food-feed cropping system [18, 27]
- [g]. Forage production and multipurpose use e.g. *Sesbania rostrata*; *L. leucocephala*; *Gliricidia sepium*; *Caliandra spp.* in the three strata forage [46, 47]
- [h]. Indigenous animal genetic resources, including dairy goats [5, 48, 49]
- [i]. Inter-cropping with cereal e.g., rice-*Sesbania rostrata*, alley cropping and relay cropping [50].
- [j]. Investment on agriculture [7, 34, 51, 52]
- [k]. Listening to farmers [24]
- [l]. Negative effects of climate change on reduced animal performance: [53]; and on crops [54]
- [m]. Non-conventional feed resources [11, 55, 56]
- [n]. Reviews on improved feed utilisation: [27, 57]
- [o]. Reduced methane emission by feeding nitrate salts is feasible [58-61]
- [p]. Silvopastoral systems; [1, 5, 62, 63], and with reference to palm oil [63]; oil palm biomass and by-products in silvopastoral systems [64].

## Pathway for animal-agriculture to cope with climate change

Two key factors that will affect animal performance are heat stress and feeding and nutrition. Nevertheless, the notion of heat stress must be kept to the barest minimum, and with efficient feeding and management. As such, the strategy will be to enable the animals to recover from the harsh impacts with high quality dietary feeds. Table 7 summarizes the impact of climate change on animal production. Table 7.

Strategies for ensuring productivity from animals and coping with climate change present major challenges and it is essential to establish priorities for effort. Several important strategies merit application to cope with climate change, to support the development of sustainable agriculture and to promote rural economic growth. These have been reviewed by [65] and may be summarized as follows:-

- [a]. Develop LFAs in humid, sub-humid and arid and semi-arid AEZs
- [b]. Develop sustainable food production systems from a diminishing resource base with all possible alternatives;
- [c]. Promote innovation (for example, food-feed systems);
- [d]. Ensure that high priority is given to R and D and farming systems research using systems perspectives and community-based participation with researchers and extension personnel;
- [e]. Pursue new mitigation and adaptation R and D pathways;
- [f]. Develop systems approaches that involve the biophysical environment and natural resource use and management and their interactions [50], and
- [g]. Systems perspectives, methodologies, together with FSR are fundamental in driving technological improvements and yield-enhancing strategies that improve NRM and agricultural productivity, resolve farmer's problems and sustain food security for human welfare.

The ADB studied the economics of climate change in South-East Asia (Thailand, the Philippines, Indonesia, Vietnam and Singapore) as a basis for formulating policies to include impact assessment, adaptation and mitigation analysis. The study indicated that agriculture-dependent economies could contract by as much as 6.7% annually. It reported that mitigation could potentially sequester carbon by 3.04 tCO<sub>2</sub>/ha/yr, reduce CH<sub>4</sub> emissions by 0.02 tCO<sub>2</sub>-eq

## Empowerment, education and enhanced impacts

### Impact on meat and milk supply

Whereas dietary meat is not a staple every day, milk is drunk in small quantities daily, making a significant contribution to nutrition and health, and possibly also income. At the heart of all development effort, education and empowerment are supreme. Empowerment enables people to have control and use of their own resources and their own agenda, have access to information and services, and a developed capacity to determine their own future. In the long term this development also enhances self-reliance and the ability to be resourceful to the extent possible with minimum dependence on external inputs [37]. (Plate 9).

### Empowerment and education of women and their role in animal-agriculture

Women play a significant role in maintaining the three pillars of *food security: food production, food access and food utilization*. Empowerment of women has powerful beneficial effects on agricultural

**Table 7. Comparison of varying capacity and live weight production of cattle from native pastures under oil palm and improved pastures in the open [39].**

Type of forage	Stocking rate (Heads/ha)	Age of oil palm (yr)	Live weight gain		Reference
			(g/head/day)	(Kg/head/yr)	
Native forage under oil palm	3	1-3	261	285	Chen and Othman
	2	4	321	234	
	1	4-5	380	138	
Improved pasture in the open	6	Guinea-Napier	316	796	Chen (1985)
	4	Guinea-legume	319	465	

development to include *inter alia* decision making, food and nutritional security, health, productivity and stability of farm households. Very recent FAO data based on internationally comparable data indicate that women comprise 4 % of the labour force in developing countries, the female share of the agricultural labour force ranges from about 20% in Latin America to almost 50 % in Sub-Saharan Africa, eastern and southwestern Asia.

There are two important findings that reflect the importance of women and children in the ownership and management of animals:-

- Gender differences are very noticeable in respect of small animals. The relationship of women, children are greater with small animals: chickens, ducks, goats, sheep, pigs, quails and rabbits for reasons of convenient size, easy management. The major advantages are the contribution to food production and household nutritional security.
- An assessment of the success or failure of several development projects indicated that successful development projects invariably had women participants.

At the heart of all education and training is empowerment. Empowerment enables people to have control and use of their own resources and set their own agenda. They should have access to information and services, and a developed capacity to determine their own future. In the long term this development also enhances self-reliance, that is, ability to be resourceful to the extent possible with minimum dependence on external inputs. The education of women has powerful beneficial effects on agricultural development to include *inter alia* decision making, food and nutritional security, health, productivity and stability of farm households.

The intent to manage and use their own resources, and articulation of this is a direct result of empowerment and self-reliance. In this context it is instructive to summarise a case study on the uniquely success story of ‘Operation Flood’ in India. This is as follows: -

- The producers of large supplies of buffalo milk from the rural areas of the Kaira district to Bombay (now Mumbai) were disturbed by the unfavorable price and market conditions they were exposed to.
- In January 1946 they met and established resolved to establish Milk Producers ‘Societies in each village of the Kaira district in order to collect milk from their members. The Kaira Milk cooperatives consists of a two- tier system with the District Milk Producers Cooperative at the central level, and

more than 850 village Milk Producers Cooperative Societies at the village level.

- The formation of these provided apposition of strength to argue for a guaranteed price of milk higher prices of milk in the strong Bombay market, as well as marginalize the middlemen who exploited the marketing system.
- Each Cooperative Society maintains a Milk Collection Centre with trained staff. Milk is received morning and evening, tested for quality, and payment is made for the milk delivered at the previous collection.
- Today, the Kaira District Cooperative Milk Producers Union is Confederation supplying milk to the dairy plant owned by the producers, and for the various products: butter, cheese, ghee, milk powder, baby foods and chocolate. AMUL the trade name under which the products are marketed is well known throughout India. AMUL is the acronym for Anand Milk Union Limited, as well as ‘beyond price’ in the local language.
- A comparison of incomes from buffalo milk and cow milk in villages with and without cooperatives indicated that the respective figures were 51 % and 62 % in the former [66].
- The AMUL complex continues to demonstrate the benefits of integrated education, research, extension and training activities, and the importance of cooperatives. The production and wide use of UMBL for the dairy animals and the recent construction of plants to protect dietary proteins is a measure of effective training, rapid adoption of innovative feeding technology and self-reliance.
- The Cooperative Dairy Development in Anand has brought about profound social and economic impacts. The whole fabric of rural life has been enhanced along with increased milk supplies and nutritional well-being, higher income, household stability, village cohesiveness, increased security and. increased employment opportunities.

The Anand model of India’s ‘Operation Flood’ ‘integrates many important elements. It involves some 13 million farming families and processing about 90 million kg of milk per year, making farmers shareholders of the whole chain of marketing and processing of milk, with resultant improvements to their livelihoods.

### Guiding principles for increasing agricultural productivity

- Agriculture must continue to spearhead and expand food production systems, help to reduce nutritional problems, food in security and malnutrition

**Plate 9. Empowerment of women in farming systems and goat production in Chulindanda, Nepal.**

- Food should be abundant and reasonably priced.
- R and D on production systems, food security and climate change merit high priority.
- R and D initiatives in rural areas need coordinated community-based participation of farmers, researchers and extension personnel.
- The development of productivity-enhancing new technologies must take into account useful elements of traditional systems.
- Small farmers, including women, if empowered, could make a big difference through their productive and innovative capacity, efficiency, and numerical strength.
- Successful models should be developed for demonstration, replication and expansion.
- Extension agencies and workers should promote informal training, open and easy communication, discussion, innovation, study tours and networking to vitalise agriculture [1].

### Investing in animal - agriculture

Increased investments in animal agriculture are both justified and needed for the development of LFAs, given their potential impact on increased productivity, poverty and food security, improved livelihoods and the environment. Studies in China [50] and in India [51] have shown that the returns on investments are much higher in very poor areas. It has been proposed in the Indian context that improving agrarian prosperity and rural development should focus on five pillars: public investment, credit, infrastructure (roads, transport and agro-processing), stable markets acknowledge transformation of farmers [67]. Similarly, it has been reported that the estimated returns to agricultural R&D are high – enough to justify even greater investment of public funds [68].

There are a number of emerging issues all of which will affect the animal and its products to predict when diseases will strike the animals, it is most essential therefore to maintain high standards of good hygiene and cleanliness on the farm. It is just as important derecognize the pathways to mitigate waning agriculture, as well as it stands formation through assertive and concerted informal training, involving six fundamental pathways:-

- Intensify the use of the more promising indigenous breeds within- species to demonstrate potential capacity;
- Improve NRM through better coordination, instructional reform and policy;
- Promote intensive use of productivity-enhancing technolo-

- gies that are adapted to climate change [33];
- Influence economic agricultural growth that is pro-poor and can induce poverty reduction;
- Develop the full potential capacity of food systems to produce abundant food that is accessible;
- Demonstrate efficient NRM, poverty reduction, food security and environmentally sustainable agriculture;
- Provide higher priority to the more remote small farms and
- Empower farmers to be agents of poverty reduction and stewards of the environment in community-based development activities.

### Small ruminants as the entry point for development

The ultimate challenge in animal-agriculture is demonstrable economic and good responses in animals that can reflect environmentally sustainable production. In the arid and semi-arid areas, the value of small ruminants especially goats and sheep [62], increases with increasing harshness of the biophysical environment and decreasing quality of available feed resources. These species have a multifunctional role in which their contribution to nutritional and food security and especially to survival is paramount. They should therefore be given high priority in the development of rainfed areas (Figure 2). The development of crop-animal systems can significantly contribute to sustainable food production.

Concerted application of a blend of traditional knowledge and new technologies and management systems that are adapted to climate change and can give increased productivity per unit of land or labor impacts (Figure 3). However, the varied and complex issues related to such development require an inter disciplinary approach combined with effective development policy to achieve environmentally sustainable food production. (Figures 2 and 3)

### Conclusions

- Increasing food production remains the defining future concern. Agriculture must therefore continue to spearhead and expand food production systems, help to reduce nutritional problems, food insecurity and malnutrition.
- The objective is abundance of reasonably priced food, access, and reduced hunger and malnutrition. This pathway must have the central objective of demonstrating improved environmentally sustainable animal-agriculture.
- Vigorous R and D on NRM, production systems, food inse-

Figure 2. The use of goats as the entry point for developing less favored areas.

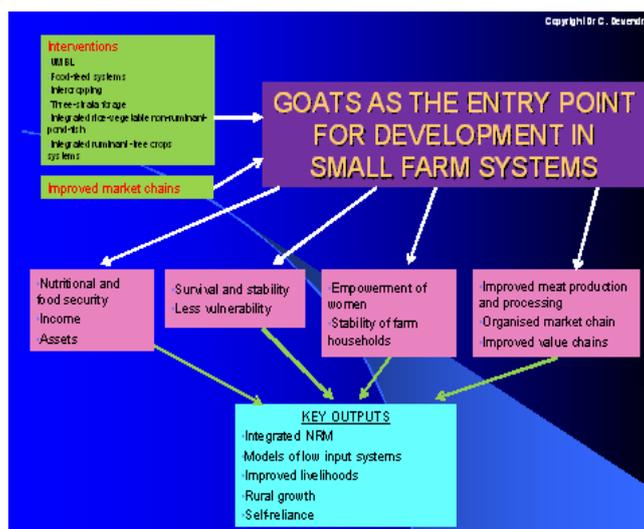
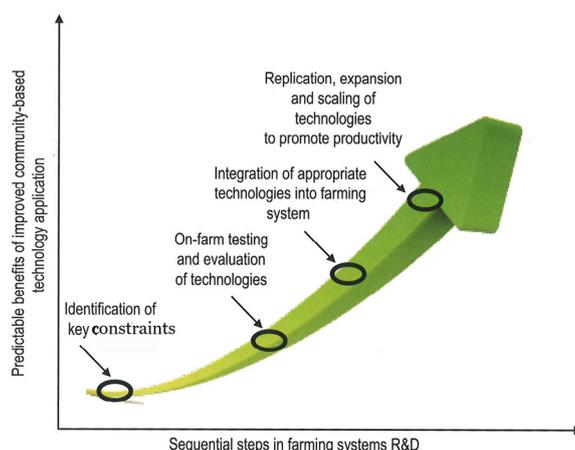


Figure 3. Illustration of resolution of constraints, impacts and expanded agricultural development.



curity and the looming effects of climate change merit high priority. These are overwhelming challenges for agriculture and more complex with animal-agriculture (Table 4).

- The development of productivity-enhancing new technologies must recognise traditional systems, new technologies, and pathways to their adoption, replication and intensification that link with post-production in supply value and food chains.
- Increased investments in small farm systems have potential payoffs given the enormous productive and innovative capacity, models of efficiency, growth and dominance in the region in the future.
- R and D initiatives in rural areas needs coordinated community-based participation of farmers, researchers and extension personnel is necessary for the duration of the project.
- FSR methodologies and a systems approach are necessary to deal with the complexities of the biophysical environment and the interactions within the natural resources.
- Integrate appropriate ruminants as an entry point for the development of LFAs.
- Invest in, and transform the most marginalized LFAs into systems with demonstrable potential, and promote their replication and expansion.
- Promote the empowerment of women and their participa-

tion in farming systems.

- Pursue informal training, encourage the freedom of easy contact, communication, discussions, innovation, visits and networking as additional means to vitalise agriculture.
- Central to which is improving education [36].

For a global total of about 2.6 million resource-poor small farmers and the landless, the enduring hope is improved livelihoods and self-reliance with access to new knowledge, sustained food security, pride in animal-agriculture, reduced poverty and longevity. The immediate need is collective engagement and policy commitments to fulfill those hopes, and in the long term, wish for an agricultural landscape that is in harmony with nature. The urgency to resolve is far greater than continuing discussions which increasingly pale into being academic. Assertive, well considered and coordinated R and D, institutional commitment with a strong policy framework are urgently required in which vision can lead the way.

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