

## Food-Feed Systems in Asia - Review -

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**ABSTRACT** : This review paper discusses the relevance and potential importance of food-feed systems in Asian agricultural systems, and in particular the role and contribution of legumes to these systems. A food-feed system is one that maintains, if not increases, the yield of food crops, sustains soil fertility, and provides dietary nutrients for animals. It involves a cropping pattern within which the feed crop has many beneficial effects without competing for land, soil nutrients and water with the food crops. The agricultural environment is described with reference to the priority agro-ecological zones and prevailing mixed farming systems in Asia. Within these systems, animal production is severely hampered by critical feed shortages which can however, be alleviated by the integration of suitable leguminous forages into the cropping systems. The review also focuses on the role and potential importance of leguminous forages in terms of biodiversity, their uses in farming systems, beneficial effects on animal performance, and draws attention to six case studies in different countries that clearly demonstrate many benefits of developing such food-feed systems. Considerable opportunities exist for widening the use of forage legumes in the development of systems with several complementary advantages (e.g. fenceline, cover crops, fodder banks, forage source and erosion control) to improve the development of sustainable crop-animal systems in Asia. (*Asian-Aust. J. Anim. Sci.* 2001. Vol. 14, No. 5 : 733-745)

**Key Words** : Forage Legumes, Food-Feed System, Mixed Farming, Cropping Systems, Crop-Animal Systems, Animal Production, Natural Resources, Sustainability.

### INTRODUCTION

South East Asia is a region of dynamic changes. Until the recent Asian economic crisis, the region has achieved spectacular economic growth, with increases in gross domestic product (GDP) of 4 to 9% in previous few years. The region has political maturity and increasing regional cooperation. Agriculture makes a significant contribution to the total GDP (11-53%), and 43-88% of the human population in the region depends on this sector for their livelihood. Livestock in individual countries contributes 6-20% to agricultural GDP, and plays an important and varied socio-economic role. In the Mekong countries and China, there is an increasing shift from centrally planned to open-market economies.

Increasing food production, especially that of animal origin, and poverty reduction is a compelling objective. The task is exacerbated by several factors which include *inter alia*, population growth, urbanisation, income growth, largest demand increases being found in Asia, supplies being unable to meet the demand, and changing consumer preferences. The awesome scenario is that current supplies will not be

able to meet projected increased demand for meat (mainly beef, pork and poultry) and milk which for East Asia is 110-157% and 111%, and South East Asia 100 and 200%, respectively by year 2020. The implications, opportunities, and challenges involved in this process in the developing countries in the next 20 years, is now represented in the term Livestock Revolution (Delgado et al., 1999), in which the ILRI strategy to 2010 is making the Livestock work for the poor (ILRI, 2000).

Agriculture has tended to emphasize crop production, notably rice, based on high inputs and intensive systems, resulting in enormous benefits through the "Green Revolution". The focus has been mainly on the over-populated irrigated areas which are experiencing declining yields. To further increase food production, attention must now be given to the neglected rainfed lowland and upland agro-ecological zones (AEZs) that have been bypassed by the Green Revolution, where major research and development opportunities exist to increase productivity and directly address poverty reduction and the environment. This is justified further by the relatively large human and animal populations in these areas. Considerable opportunities exist for improving both crop and animal production systems for the poor people in these areas.

### AGRICULTURAL ENVIRONMENT

It is pertinent to keep in perspective the agricultural environment that relates to prevailing farming practices.

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The priority AEZs and systems relevant to Asia are:

- Rainfed temperate and tropical highland system mainly the Hindu Kush/Himalayan region
- Rainfed humid/sub-humid tropical system -mainly countries in Indo-China, South East Asia and the South Pacific islands.
- Rainfed humid/sub-humid sub-tropical system mainly countries in South Asia, excluding Nepal and Bangladesh
- Irrigated/humid/sub-humid tropical system -mainly countries in Indo-China, South East Asia and South China
- Irrigated arid/semi-arid tropics and sub-tropics systems mainly Pakistan and India.

Within the rainfed humid/sub-humid tropical AEZs, two broad areas are recognized: rainfed lowlands and 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 characteristics of the lowlands and uplands have recently been reported, and in terms of soil moisture stress these approximate more to the humid areas (Devendra et al., 1997). 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.

The lowlands have larger areas of arable and permanent cropland, which account for the greater crop production in these areas. However, with increasing use of these there is an increasing shift to use the upland areas. The data also indicate importantly that about 51% of the cattle and 55% of the small ruminant populations in Asia are found in these AEZs. Unfortunately, no data were available for the sizes of buffalo and non-ruminant (pigs 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 (Chantalakhana, 1994).

### DEMAND-DRIVEN CONSEQUENCES

Associated with the projected need for more foods of animal origin in Asia in the future, are a number of demand-driven consequences, which need to be addressed. These include *inter alia*:

- Stress on the use of natural resources
- Emphasis on increased productivity *per animal* and per hectare
- Improved efficiency in feed resource use
- Intensification of animal production systems
- Increased concentration of animals in peri-urban

areas

- Increased disease risks, pollution and human health issues, and
- Urbanisation associated with increased consumption of pork, mutton and poultry.

The stress on the use of natural resources (land, water, crops and animals) will be unprecedented, and will necessitate efficient use in a way, which can balance maximizing productivity and environmental integrity. Among the natural resources, land use systems will be paramount. The available rainfed area is about 82% of the land area in Asia in the priority AEZs. The largest areas are found in the arid/semi-arid zones and also humid/subhumid zones (TAC, 1992). It also gives an indication of the relative size of the human populations and food demand in the different AEZs.

### THE RELEVANCE OF MIXED FARMING SYSTEMS

Throughout Asia, mixed farming is the overriding pattern of agriculture, and is reflective of the traditional form of agriculture in Asia. These mixed farming systems have certain distinctive characteristics across AEZs (Devendra, 1995):

- Diversification in the use of production resources
- Reduction in, and spread of, risks
- Preponderance in small farms
- Use of large populations of ruminants (buffaloes, cattle, goats and sheep) and non-ruminants (chickens, ducks and pigs)
- Integration of crop and animal production
- Animals and crops play multi-purpose roles
- Low inputs use and traditional systems, and
- Involves the three main agro-ecosystems (highlands, semi-arid/arid tropics, and sub-humids/humid tropics).

Mixed farming systems, which are synonymous with crop-animal systems, are one of three primary production systems identified by Sere and Steinfeld (1996) in a description of world livestock production systems. These systems are especially important in Asia in terms of area, the extent of poverty, integrated natural resource management, and opportunities for increased food production (Devendra, 1995). The largest growth in production has been and continues to be, and the industrial or peri-urban landless systems are demand-driven and account for about 34% of the total meat, and nearly 70% of the egg production. In Asia, it was found that the landless production systems produced twice as much meat as that from the rainfed mixed farming systems. Past trends showed that between early 1980 and 1990, industrial livestock

production grew at 4.3% per year which was twice the growth of mixed farming systems (2.2% per year) and six times that of pastoral systems (0.7% per year).

These production trends are expected to continue in Asia, emphasizing the need for improved management of the natural resources. Although industrial systems are expected to grow at a faster rate, good opportunities exist for expanding crop-animal systems, especially into the rainfed lowland and upland areas where both research and developments have been generally sparse.

Animal production systems involve both ruminants and non-ruminants within the mixed farming scenario, and productivity from them is dependent to a very large extent on the efficiency of use of the available feeds. With ruminant production systems, there are three categories: extensive systems; systems combining arable cropping (roadside, communal and arable grazing systems, tethering, and cut-and-carry feeding); and systems integrated with tree cropping. These production systems are unlikely to change in the foreseeable future. New proposed systems and returns from them would have to be demonstrably superior and supported by massive capital and other resources (Mahadevan and Devendra, 1986; Devendra, 1989). However, as is evident in dairying, there will be increasing intensification and a shift within systems, especially from extensive to systems combining arable cropping, induced by population growth and intensity of land use. This situation is increasing likely with decreasing availability of arable land in many parts of South East Asia. The principal aim should therefore be improved feeding and nutrition, in which the objective is maximum use of the available feed resources, notably crop residues and low quality roughages, and also various leguminous forages as supplements.

Within mixed farming systems, the economic contribution of animals becomes even more significant in the context of the following beneficial effects:

- Complementary interactions with rice in which the products (rice, animals or fish) are additive, and rice-based systems become more sustainable
- Development of low input integrated systems
- Nutrient recycling and contribution to soil fertility
- Positive environmental effects that have economic, ecological and sociological benefits, and
- Alleviation of rural poverty and improved food security in rainfed AEZs.

#### **IMPORTANCE OF AVAILABLE FEEDS AND NUTRITION**

Within crop-animal systems, the availability of feeds and their efficiency of use throughout the year

represent the most important constraint affecting the productivity of animals. The problem is acute in view of the long dry period of about 4-7 months which severely affects crop production and the availability of feeds. The importance of developing sustainable food-feed system is obvious, and collaborative research in this area is therefore an important strategy.

A major concern in rainfed lowland and upland farming areas associated with the attainment of high yields of both rice and non-rice crops and sustaining adequate levels of soil fertility is the provision of year-round supply of feeds for animals. In rainfed lowland rice production systems, the animals are normally grazed on fallow land after the rice harvest and offered mainly rice straw and grasses during the cropping cycle. The availability of poor quality feed in a rice-fallow system undoubtedly limits the productivity of the animals. Another negative effect of the feed scarcity within the farm is the overstocking of communal grazing lands, leading to its degradation and the destruction of forests in search of feeds for ruminants.

Additionally, the inadequacy of feed supplies to support the number of draft animals has direct negative effects on crop productivity as a result of delayed land cultivation. While the development of high yielding and early maturing rice varieties has allowed the introduction of cash crops after rice in rainfed areas resulting in increased cropping intensity, this has reduced the grazing areas available for animals. The availability of feeds especially for ruminants in rainfed and irrigated environment is thus becoming more critical as cropping intensifies. Also, farm landholdings continue to decline and communal grazing areas are also becoming progressively unproductive.

#### **CONCEPT OF FOOD-FEED SYSTEMS**

In mixed crop-animal farming systems, the development of a food-feed system is therefore highly appropriate, and an important strategy. An ideal food-feed system is one that maintains, if not increases the yield of the food crop, sustains soil fertility and provides dietary nutrients for animals. This will require a cropping pattern wherein the feed crop provides many beneficial effects without competing for land, soil nutrients and water with the food crop. Relay cropping of leguminous forage or dual-purpose crops, utilization of rice herbage, planting of leguminous shrubs and grasses along bunds and terraces are some ways by which forage can be produced. The amount and availability of forage will vary depending on the agroecosystem (irrigated, rainfed, flooded lowland or upland), cropping intensity, tillage requirement, labour availability and other socioeconomic factors.

In the irrigated lowlands, feeds for ruminants come mainly from cereal straws, grasses from non-rice areas, herbage from rice bunds, and weeds associated with the rice crop. In rainfed areas, relay cropping of food, leguminous green manure, forage and dual-purpose crops, and multi-purpose trees are systems that can provide large quantities of biomass suitable for ruminant feeding. A potentially important approach for increased forage production in rice areas is technology associating forage production with green manure production, incorporating a food-feed crop or both. These technologies will provide forages of high nutrient content, benefit the subsequent rice crop and are acceptable to farmers. Across rice ecosystems, full utilisation of available land for forage production by planting grasses on bunds and fallow areas, and leguminous trees and shrubs in homesteads and fencelines, can substantially increase the amount and quality of feeds available to ruminants.

The development of food-feed systems is appropriate for both the lowland and upland situations, and are identified with three principal advantages. Firstly, the introduction of legumes, mainly annuals, can provide much needed forage for ruminants, enhance rice production, and increase soil fertility. Secondly, the complementary roles of the crops and animals and their additive effects can promote nutrient recycling leading to the development of sustainable agriculture, and the protection of the environment. Thirdly, good opportunities exist for incorporating the use of tree legumes with complementary advantages of forage production, fuel wood supply, role in fenceline, and enrichment of soil fertility in the lowland and upland areas.

### THE ROLE OF FORAGE LEGUMES

In a historical context, significant research has been undertaken in Asia on the potential value of forages, especially the leguminous types. In the South East Asian region much progress has been made, notably in the development of feed resource availability and use, specifically on the evaluation and selection of improved grasses and legumes. Successive Australian-funded projects over the last 25 years, and more recently the work of Centro Internacional de Agricultura Tropical (CIAT) on acid soils has contributed to these studies. As a result, key species have been identified for the different AEZs, however, these programs have tended to emphasise herbaceous perennial species. Annual crops are perhaps more appropriate for intensive food crop systems, where fallows are no longer available or of less than six months duration. Furthermore, research with multipurpose trees has concentrated on a very narrow range of germplasm (Devendra et al., 1997).

In South Asia, by comparison, in the more irrigated wetland areas, single, double or triple cropping systems are common. Leguminous forages have been introduced but are restricted to small areas in Haryana, Punjab and Uttar Pradesh in India, and the Punjab province in Pakistan. Cowpea, berseem and lucerne have been used, but much more can be done to extend the incorporation of legumes into cropping systems (Devendra et al., 2000). In Bangladesh, annual legumes are being introduced into rice-based systems either as relay crops or catch crops replacing short-term fallow.

Options to extend the use of leguminous forages include under sowing food crops, such as rice with annual herbaceous legumes as intercrops or relay crops; introducing leguminous leys as sequence crops in rotations; improving natural fallows with legumes; establishing leguminous cover crops in tree crop plantations; and developing agroforestry systems based on multipurpose trees, such as alley farming (Devendra et al., 2000). The following sections provide a discussion on three main areas.

### Biodiversity

The family *Leguminosae* with approximately 650 genera, and more than 18,000 species is the third largest family of flowering plants (Gutteridge and Shelton, 1994). Its species are found in temperate and tropical zones, from arid to humid ecosystems, from acid to alkaline soils, in highlands, lowlands and savannas, and there are even few aquatic legumes (NAS, 1979). Asia in general is a rich source of genetic diversity of grain legumes or lentils. South East Asia had been frequently overlooked as a center of diversity of tropical forage legumes, given the dominance of South and Central America in this respect (Hutton, 1977); but Williams (1983) identified 68 genera in the subfamily *Papilionoidea* alone whose natural distribution extends to tropical Asia. South East Asia in particular is the origin for many of the soybean (*Glycine max*), groundnut (*Arachis hypogea*) and mungbean (*Vigna radiata*) genotypes. As an indication of the genetic variability in these species, only a grain legumes collection in Madang (Indonesia) had 2312 accessions, 76% of which were native to Indonesia (Mejaya, 1994).

Relatively recent collection missions to most South East Asian countries (Shultze-Kraft et al., 1989; Shultze-Kraft et al., 1993), resulted in a considerable broadening of the genetic base of *Desmodium* species and their related genera (*Dendrolobium*, *Phyllodium*, *Tadehagi*), as well as *Pueraria* species. Other genera represented in those collections were: *Aeschynomene*, *Alysicarpus*, *Cajanus*, *Clitoria*, *Crotalaria*, *Flemingia*, *Galactia*, *Mucuna*, *Rhynchosia*, *Teramnus*, *Uraria*, *Vigna* and *Zornia*. *Sesbania grandiflora*, *Paraserianthes*

*falcataria*, and few species of *Erythrina* are some of the multi-purpose leguminous trees native to South East Asia, but many other genera (e.g. *Leucaena*, *Gliricidia*, *Albizia*, *Calliandra*) have been introduced, and are now well adapted to the conditions prevalent in the region (Gutteridge and Shelton, 1994). Thus, the choices within the availability of woody legumes for agroforestry options have been considerably widened. Table 1 summarises identified characteristics of adaptation to climatic and soil variations for some of the forage legume genotypes recently evaluated in South East Asia.

#### Uses in farming systems

The diversity of forage legumes in terms of adaptation, morphology and growth habits, and some of their intrinsic attributes, such as nitrogen (N) fixing ability, high nitrogen content and high quality for animal production, makes members of this family suited for most agricultural systems in Asia. Table 2 indicates their potential uses in different agricultural systems (Horne and Stür, 1999).

Forage legumes can be exclusive within animal production systems, such in the case of fodder banks and grass-legume mixtures, but in others, forage legumes can be a component of crop-animal systems, providing feeds and also interacting with the annual or perennial crops cultivation. Some of these options are legumes in hedgerows, live fences, cover crops in plantations, alley cropping, improved fallows and multiple cropping with annual crops.

In the case of protein or fodder-banks, legumes, mainly woody perennials, are grown alone in compact blocks, and are most frequently used in cut and carry systems than under grazing (Ella et al., 1989; Ella et

al., 1991). Forage legumes can be also grown in association with grasses, and used either under grazing or cut and carry systems. In the case of grass-legume mixtures managed under grazing, the persistence of herbaceous legumes has been less (Hare et al., 1999a; Hare et al., 1999b) than observed for legume trees and shrubs (Ella et al., 1991).

Contour hedgerows constitute another system in which forage legumes are incorporated into crop-animal systems. These systems are effective in minimizing soil erosion, and in some medium fertility soils have been able to maintain crop productivity after using the legume tree prunings as mulch (Laquihon and Pagbilao, 1994), but these were not sufficient when phosphorus was the most limiting nutrient. These reasons, plus the high investment involved in planting legume shrubs and trees, may be reasons why farmers' adoption has been limited, in contrast to adopting hedgerow options involving natural vegetation and grass strips (Nelson and Cramb, 1998).

Forage woody legumes can also be planted in alley cropping systems. In these, cash crops are grown between rows of leguminous trees and shrubs (Nitis, 1999), which are frequently pruned, and the foliage harvested is either left as mulch, incorporated as green manure, or partially used as animal feed (Kang, 1993; Pezo and Ibrahim, 1998). In South East Asia, *Calliandra calothyrsus*, *Leucaena leucocephala*, *Gliricidia sepium* and *Paraserianthes falcataria* are successful under these systems (Dierolf and Yost, 1989; Dierolf et al., 1989; Handayanto et al., 1994). All these are deep-rooted legume shrubs and trees which can regrow after pruning, therefore substantially contributing to nutrient cycling by getting nutrients from depths which annual crops cannot reach (Dierolf

**Table 1.** Adaptation to different climatic and soil conditions for some herbaceous and woody forage legumes evaluated in South East Asia

Species	Climate			Soil fertility and acidity		
	Wet tropics with no or short dry season	Wet/dry tropics with long dry season	Cooler tropics (e.g. high elevation)	Fertile (neutral to moderately acid soils)	Moderately fertile neutral to moderately acid soils	Infertile (extremely acid soils)
<b>Herbaceous</b>						
<i>Arachis pintoii</i>	**		*	**	**	
<i>Centrosema macrocarpum</i>	**	*	*	**	*	
<i>Centrosema pubescens</i>	**	*		**	*	
<i>Stylosanthes guianensis</i>	**	**	*	*	**	**
<b>Trees and Shrubs</b>						
<i>Calliandra calothyrsus</i>	*		**	*	**	
<i>Desmanthus virgatus</i>	**		**	**	*	
<i>Desmodium cinerea</i>	*	*		*	*	
<i>Gliricidia sepium</i>	**	**		*	**	
<i>Leucaena leucocephala</i>	**	**	*	*	**	**

\*\* : Recommended, \* : Possible, Blanks : Not recommended.

(Horne and Stür, 1999)

**Table 2.** Suitability of forage legumes for different uses

Species	Protein/ fodder banks	Grazed plots	Living fences	Hedge- rows	Improved fallow	Cover crops in annual crops	Cover crops in tree plantation	Ground covers for erosion control	Supple- ments for dry Season	Legume leaf meal
Herbaceous										
<i>Arachis pintoi</i>		*					**	**		
<i>Centrosema macrocarpum</i>	*				**	**	*	*		
<i>Centrosema pubescens</i>	*				**	**	*			
<i>Stylosanthes guianensis</i>	**	*		*	**	**	*		**	**
Trees and Shrubs										
<i>Calliandra calothyrsus</i>	**		*	*					*	
<i>Desmanthus virgatus</i>	**			*						**
<i>Desmodium cinerea</i>	**			**						
<i>Gliricidia sepium</i>	**		**	*					*	
<i>Leucaena leucocephala</i>	**	*		*	**	**	*		**	**

\*\* : Recommended, \* : Possible, Blanks : Not recommended.

(Home and Stür, 1999)

et al., 1989). The contour hedgerow systems are also a type of alley cropping, but apply to sloping land (Nelson and Cramb, 1998).

The use of forage legumes as cover crops in tree plantation systems (e.g. oil palm, rubber and coconut) is another practice in South East Asia, as a means to integrate animals into these systems (Stür and Shelton, 1991; Dahlan et al., 1993). Legume cover crops not only favor diversification and higher income (Reynolds, 1995), but also result in higher animal productivity, compared to the use of the native under story vegetation (Chong et al., 1994). Forage legumes help in reducing weeding costs as these compete favorably with weeds, (Chee and Faiz, 1991), controlling erosion (Stür and Shelton, 1991a), and improving soil physical and chemical properties (Zainol and Mokhtaruddin, 1993; Zainol et al., 1993), which in turn could result in increased productivity of the tree component. The implications of livestock-tree interactions in agroforestry systems in developing countries has recently been reviewed (Devendra, 1999).

There are several options for the integration of forage species with annual crops: ("ley farming"), either in rotation or inter-cropping (simultaneous or relay). This is a traditional practice in European farming, but has not been widely adopted by farmers in the tropics and subtropics, although there are promising results from research (Humphreys, 1994). These indicate that there are clear opportunities for tropical forage legumes in these systems, given that soil N availability is a key factor in maintaining crop yields, and there are genotypes of nitrogen fixing legumes for almost each environmental condition (Vallis, 1985; Ahmed et al., 1991; Myers, 1992). Leguminous forages grown during the fallow period can provide valuable cover to reduce soil and water

losses, and also contribute to increase the soil organic matter content which in turn results in increased soil water retention and decreased in resistance to root penetration, the magnitude of which vary with species (Utomo et al. 1992; Waring and Gibson, 1994). The use of forage legumes as cover crops in rotation with food crops constitutes an improved fallow. Under these circumstances legumes may contribute to weed suppression, with the consequent reduction in labour and herbicides required for the following crop (Humphreys, 1994; Wortmann et al., 2000). In Indonesia, Guritno et al. (1992) demonstrated that *Mucuna pruriens* and *Pueraria phaseoloides*, combined with mechanical weed control, were effective to control the very aggressive *Imperata cylindrica*.

One of the main purposes for growing legumes in rotation with grains and tubers are the residual effects legumes could have on subsequent crops, and in fact, most of the studies summarized in table 3 illustrates such effects. However, in rice-based systems, even if grain yields are not improved by rotation with legumes, an important contribution of the latter is in the conservation and/or recycling of soil nitrates accumulated during the dry season, which could be lost by leaching or denitrification when flooded rice is grown. A similar function could be performed by weeds, but legumes are preferred as they produce a product with economic value (George et al., 1994).

#### Effects on animal performance

Feeds for animals in Asia come from a number of sources. These include in order of importance, crop residues and agro-industrial by-products (AIBP), native and cultivated grasses, browse and tree leaves, and non-conventional feed resources (NCFR). However, the residues from cereal crops contribute to the bulk of

**Table 3.** Nitrogen fixation by legumes and yields of the subsequent crops in rotation in South East Asia

Legume	N fixed (kg ha <sup>-1</sup> )	Relative yield of subsequent crop <sup>a</sup> (%)	Reference
Rice			
Soybean ( <i>Glycine max</i> )	149-176	97-100	George et al. (1995)
Cowpea ( <i>Vigna unguiculata</i> )	60-78	112	
Mungbean ( <i>Vigna radiata</i> )	61-90	106-110	
<i>Sesbania rostrata</i>	68-154	180-183 <sup>b</sup>	George et al. (1994)
Mungbean ( <i>Vigna radiata</i> )	37-63	150	
<i>Sesbania cannabina</i>	87-112 <sup>c</sup>	146 <sup>d</sup>	Meelu et al. (1992)
<i>Indigofera tinctoria</i>	29-55	124	
Soybean ( <i>Glycine max</i> )	70-72	149	
Mungbean ( <i>Vigna radiata</i> )	67-70	146	
Groundnut ( <i>Arachis hypogaea</i> )	150-172	128-131	Toomsan et al. (1995)
Soybean ( <i>Glycine max</i> )	108-152	112-120	
Maize			
Groundnut ( <i>Arachis hypogaea</i> )	75-150	114-137	Toomsan et al. (1993)
Groundnut ( <i>Arachis hypogaea</i> )	101-130	117-135	McDonagh et al. (1993)
Cassava			
<i>Macroptilium atropurpureum</i> ,	42	150	Gibson and Waring
<i>Stylosanthes hamata</i> cv. <i>Verano</i>	31	127	(1994)

<sup>a</sup> Compared to the control treatment, in most cases fallow with native grasses and weeds, <sup>b</sup> Total DM yield 9-10 weeks after planting, <sup>c</sup> Assumption: N fixation represents 50% of the nitrogen accumulated in the legumes biomass, <sup>d</sup> Data for the 2<sup>nd</sup> year. During the 1<sup>st</sup> year, there were no significant differences with the control treatment.

the ruminant diet. In South Asia, millions of tonnes of cereal straw (wheat, rice, maize, sorghum, millet) are produced of which only 40~50% are utilised for animal feeding (Devendra et al., 2000). This is particularly true in many of the irrigated areas where cropping intensity is high. Conversely, the more nutritious AIBP feeds for ruminants are used at not more than 10% of the diet. In South East Asia, the use of cereal straws, particularly rice straw, is limited to 30% of the ruminant diet, but is fed to about 90% of the large ruminant population (Devendra, 1996). The cereal straw-based diet is fortified by a variety of conventional and non-conventional feedstuffs, notably grasses and browse plants.

Leguminous forages have significant effects on improved animal performance, given their diversity as well as potential benefits. These *inter alia* are as follows:

- Provide variety in the diet
- Increase dry matter intake, digestibility and efficiency of feed conversion
- Provide fermentable nitrogen for efficient rumen function and a source of by-pass proteins
- Provides also a source of minerals, vitamins, and carotenoids which benefits the animal
- Improved meat and milk production
- Faster duration to slaughter weight and marketing
- Improved reproduction

- Improved dung quality which in turn benefits soil fertility
- Reduced cost of production, and
- Improves the rate of passage.

Given the dependence of ruminants on mainly cereal straws and free grazing, the effects of supplementing leguminous forages are very marked. The use of more nutritious and high protein forage supplements to support higher productivity is therefore an important approach. The potential value of such forage supplements to various animals and their significant effects on productivity have recently been reported (DMello and Devendra, 1995). The integration of forage crop production into the dominant cropping system not only benefits animal production, but also the sustainability of the whole farming system.

However, the wider use of leguminous forages is not without problems since some species have a variety of anti-nutritional factors that can have side effects and reduced performance in animals (Makkar and Becker 1999). It is important to ensure therefore that optimum levels of the forage are fed to individual species to get the best performance (DMello and Devendra, 1995) together with the use of practical measures, e.g. sun drying, to reduce the effects of these deleterious substances.

## CASE STUDIES

The following seven case studies demonstrate the potential importance and benefits of integrating forage legumes into crop-animal systems, and emphasize opportunities for more development effort in the humid AEZ.

### Rice-dairy cattle system (Bangladesh)

*Lathyrus sativus*, a fodder legume, was planted as a relay crop in standing Aman rice in October in the two villages in Mymensingh district. The top portions of the fodder were harvested in January and made into hay as supplement for dairy cattle at 1.0 kg/day for 28 days. Results showed that supplementation of *Lathyrus* increased milk yield by 20% compared to the 28-day milk yield obtained during the pre-supplementation period. A similar result was observed in an on-station experiment (Akbar et al., 2000).

### Upland corn-beef cattle integration (Thailand)

Baby corn production in Thailand with reference to immature and young corn ears involves the selling of the stems and leaves as feed for cattle feed to provide additional income. An oversupply of the forages during peak of harvest depresses the selling price of these feeds to the disadvantage of farmers. These feeds are then sold to cattle owners with the additional disadvantage of depletion of the soil of nutrients. The solution is for the corn-growing farmers to raise beef cattle.

Traditional corn farmers however, produce baby corn but do not integrate cattle into the system. However, a study on rotational cropping of baby corn was conducted to produce a continuous supply of stems and leaves for the animal with the introduction of beef cattle production. The results showed that the maize crop rotated in six rai (rai = 0.16 ha) planted at an interval of 18 days produced the forage component of the ration adequate for six cattle. Significant improvements in daily liveweight gain (0.7 kg) were recorded when these feeds were fed together with concentrates (Prucasri and Thanomwongwathana, 1995).

### Upland rice-animal system (Indonesia)

In Baturanta, a site in South Sumatera in Indonesia, crop-animal farming system research was conducted in an upland rice ecosystem representing a transmigration area. Four crop-animal models (A- farmers system without animals, B- system A with animals, C- gradual improvement of farming systems with animals and D- introduced farming systems with animals) were tested. Farm models C and D include the introduction of forage legumes in the cropping

pattern (CRIFC, 1995).

After six years, farm model C resulted in net income that was 67% higher compared with the farmers existing practices without animals. Rubber contributed 53%, food crops 30% and animals 17% of the total income. Farm models C and D were further tested in six villages. Two cattle, three goats and 11 chickens were introduced. Interventions include improved technologies on rice-based cropping, animal housing, animal health and feed quality. The benefits were source of draft animal power for crop cultivation, income from calves and use of cattle manure for crops. The average net income was higher for the intervention compared to the control group.

### Three-strata forage system (Indonesia)

The three-strata forage system (TSFS) is a way of producing and conserving the feed requirements of cattle and goats without harming the environment. In dryland farming areas, such as eastern Indonesia and south Asia, the system combines production of food crops, including maize, ground-nuts, cassava and pigeon pea, with herbaceous legumes, shrubs and trees to supply year round feed for stock (Nitis et al., 1990).

The increased forage production of this system allows higher stocking rates and live weight gains (3.2 animal units equivalent to 375 kg/ha/year in the TSFS compared with 2.1 units or 122 kg/ha/year in the non-TSFS). It also gives 19% more liveweight gain by cattle to reach market weight earlier, increases farm income by 31% (addition of goats to the system raises income further), reduces soil erosion by 57% by introducing forage legumes and increased soil fertility, and produces 5 m.t. of fuel wood, meeting 64% of annual needs, from 2000 shrubs and 112 trees logged twice a year. Table 4 summarises the main results. It is pertinent to note that this concept and the component technologies have been institutionalised.

### Rainfed rice-cattle system (Philippines)

In a rainfed lowland ecosystem in Pangasinan, Philippines, cropping pattern testing was conducted to compare rice-mungbean and rice-mungbean+siratiro with traditional monocrop rice. The average mungbean residue/fodder yield was 0.85 m.t./ha, while forage DM yield from Siratiro was 4.59 m.t./ha. An additional 3.5 m.t./ha from the last clipping of Siratiro was available as green manure to the following rice crop. The yield of rice following the intercropping of mungbean and siratiro was 4.39 m.t. of grain ha<sup>-1</sup> and 4.33 m.t. of straw ha<sup>-1</sup> (table 5). The incorporation of the herbage from the last cutting of the forage legumes two weeks before transplanting into the soil as green manure resulted in higher yield of the succeeding rice crop and 50-70% reduction on the cost



**Table 4.** Comparative Productivity of TSFS and NTSFS Plots (kg dry weight/plot per year)

Parameter	TSFS <sup>+</sup>	NTSFS <sup>**</sup>
Food	853	1268
Straw	750	1218
First stratum	455	-
Second stratum	310	-
Third stratum	15	-
Shrubs	-	132
Trees	-	2
Improved grasses	-	10
Native grasses	-	242
Firewood	1049	475
Cattle live weight gain (kg/animal/ 3 years)	186	166
Carrying capacity (cattle/ha)	4	2
Maximum live weight (kg/head)	300	200
Soil erosion (mm/2 years)	11	20

<sup>+</sup> Three strata forage system, <sup>\*\*</sup> Non-three strata forage system.

(Nitis et al., 1990)

**Table 5.** Intercropping Mungbean and Siratro in Pangasinan, Philippines

Cropping system	Rice yield (m.t./ha)	Mungbean yield (m.t./ha)
Rice-fallow-rice	3.0	-
Rice-mungbean-rice	3.7	1.0 - 1.5
Rice-mungbean+siratro-rice	4.5	1.0 - 1.5

of inorganic fertilizers. The adoption of the rice-mungbean+siratro cropping pattern in a 1000 m<sup>2</sup> of land can produce a total of 1.0 m.t. dry matter of forage containing 53% TDN and 12% CP sufficient to support one cattle for 4 months of the dry season.

#### Alley cropping (Philippines)

The concept of sloping agriculture land technology (SALT) has been successfully developed in the Philippines on account of the presence of about 30 million hectares of uplands, of which 80% are considered hilly. These land areas are relatively more steep and include slopes of 18 %. SALT is essentially a type of crop-animal integrating the management and use of natural resources, and involving the integration of leguminous hedgerows to reduce soil erosion, improve soil fertility and nutrients for the maize and blackpepper grown between the hedgerows, and provision of fodder for goats in confinement. The species *Calliandra* spp., *Leucaena diversifolia*, *Gliricidia sepium*, *Erythrina poeppigina*, and *Flemingia macrophylla* have been particularly promising. Laquihon et al. (1997) reported mean annual income of US\$ 1,345 per 0.5 ha for the period 1991-1993 (Table 6).

The SALT model has now led to other variants: SALT 2 (simple agro-livestock technology), SALT 3

**Table 6.** Cost and return analysis of SALT in Davao del Sur, Philippines between 1991-1993 US\$

Components	1991	1992	1993
Cash Income			
- Crop <sup>*</sup>	154.6	130.0	128.5
- Goats <sup>**</sup>	3,351.5	3,505.4	3,178.4
- Value added items <sup>***</sup>	1,516.8	1,516.8	1,516.8
Total returns	5,022.7	5,152.2	4,862.9
- Materials	2,402.6	1,381.7	1,593.0
- Non-cash items	1,754.3	1,830.5	2,014.9
Total costs	4,157.0	3,212.2	3,607.9
Net Profits	865.8	1,940.1	1,255.1
Returns on Investments (%)	20.8	60.4	34.8

<sup>\*</sup> Maize, citrus, black pepper and miscellaneous crops.

<sup>\*\*</sup> Live animals, goat meat and goat milk, <sup>\*\*\*</sup> New births, replacements and goat dung. (Laquihon et al., 1997)

(sustainable agroforest land technology), SALT 4 (small agrofruit livelihood technology) and SUPER SALT (sloping agricultural land technology). This technology has been extended for use elsewhere in the region such as in India, Sri Lanka and Laos, and also into parts of Africa.

In Nigeria by comparison, similar systems that use food or forage crops between hedges of multi-purpose trees, such as, *Leucaena* and *Gliricidia* for mulch and/or forage has been successfully developed. The improvements include soil fertility, crop yields and feed shortages for animals. A review of the role of alley farming in African livestock production (Reynolds and Jabbar, 1994) gave the following highlights.

- Maize grain the most important single food crop in Africa gave linear response yields according to the level of *Leucaena* or *Gliricidia* applied,

**Table 7.** Economic Efficiency Analysis of Cropping Patterns (1987-1992)

Cropping pattern	Outputs					Inputs			Net Income (Yuan/mu)
	Yield (kg/mu)		Value (yuan/mu)			(Yuan/mu)			
	Grain	Silage	Grain	Silage	Total	nputs	Labour cost	Total cost	
T-R	390	33650	390	360	750	160	50	210	540
W-R	675	---	611	---	611	185	50	235	376
Fallow-R	415	---	415	---	415	95	30	125	290
W-M	320	2250	256	320	476	135	40	175	301

T=Triticale, W=Wheat, M=Maize, R=Rice, \* 1 mu = 1/15 Ha.

(Wang et al., 1993)

and up to 40% increases were recorded when all the tree prunings were returned as mulch.

- Supplementation with *Leucaena* or *Gliricidia* increased the productivity (kg weaned/dam/year) of both West African Djallonke sheep and West African dwarf goats.
- *Leucaena* forage supplementation gave increased milk production in early lactation especially in the dry season when the basal diet is of poor quality.
- Economic analysis of livestock production showed that continuous alley farming was more profitable than alley farming with fallow, or conventional no-tree farming, even when the cost of clearing trees at the end of their useful life is included.

#### **Triticale rice cropping and silage production (China)**

The expanding dairy industry in temperate Beijing is dependent to a large extent of availability of both forages and concentrates. Forages, hays and especially silages are commonly used as the basal feeds. The most common silage use is from maize, but in the irrigated areas where this is produced, further expansion of arable land is impossible. Attention thus turned to the introduction of triticale, a new forage source in the more temperate areas (Sun and Wang, 1993) with rice cropping during the winter spring period in the lowlands and shift the traditional one rice cropping pattern to rice triticale double cropping. This significantly increased both grain and silage production, which in turn has had a significant effect on the promotion of dairy development in Beijing. Triticale silage is superior to maize silage and comparable to barley in chemical composition, but in terms of biomass yield and nutrients output per hectare, it outyields both maize and barley.

Research over five years (1987-1992) in Changpin, Beijing, on the introduction of triticale indicated several benefits. Table 7 indicates that among the

existing cropping patterns, triticale rice cropping gave the following results (Wang et al., 1993):

- Higher grain and silage yield compared to maize
- Highest net return
- Economic benefits of grain forage cropping patterns, essentially food-feed systems were higher than grain-grain cropping patterns, and
- Improved crude protein and fat contents in milk.

While the economic analysis is specific to crops, the inclusion of dairy production in another study increased the income even further through the use of triticale silage compared to barley silage.

#### **CONCLUSIONS**

Food-feed systems represent an important complementary strategy to increase much needed feed availability, food production and sustainable crop production systems. Their development is justified by critical feed shortages especially in rainfed areas, and can be accelerated by utilising data generated from agronomic studies on green manure production, and the wealth of information on socioeconomic studies concerning rice-based systems. A wide array of conventional and non-conventional crops have been screened in Asia for forage and green manure production by both national programmes and international agencies. Good opportunities exist therefore for incorporating the use of legumes with complementary advantages of forage production, fuel wood supply, role in fenceline, and enrichment of soil fertility in the lowland and upland areas, which together can enable improved crop-animal systems and also livelihoods of poor people in these areas.

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