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Agroforestry and Silvopastoral Systems Potential to Enhance Food Security and Environmental Sustainability in South East Asia

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Abstract

Agroforestry involves tree crop options while silvopastoral systems link with animals to provide important opportunities for increasing agricultural productivity and environmental sustainability. Additionally, agropastoral systems combine crops, animals and trees. The bio-economic and environmental potential of these systems are underestimated. Integration of ruminants with coconut, oil palm and rubber plantations enables diversification, stratification and beneficial synergistic crop-animal-soil interactions such as increased animal protein supplies to meet projected human requirements up to 2050 and food security: The available feed biomass is the primary driver of economic impacts, along with competition for nutrients and moisture, tree canopy effects, species of ruminants and management issues. The benefits of integration in oil palm from 21 case studies showed increased yield of 0.49–3.52 mt of fresh fruit bunches/ ha/yr; 30% increased income; 47-60 % savings in weeding costs by; and an internal return of 19%. Anthropogenic gasses and climate change are of concern, but mitigation measures and improved agronomic options like planting tree legumes, can enhance carbon sinks through enrichment of soil organic matter The ADB has recently reported that mitigation can potentially sequester carbon by 3.04 tCO_2/ha.yr, reduce CH_4 emission by 0.02 tCO_2 -eq /ha/yr, and reduce N_2O emissions by 0.02-2, 30 tCO_2-eq/ha/yr. With ruminants fed on low protein cellulosic materials, nitrate salts potentially reduce methane production to minimal levels. A coherent policy framework for silvopastoral systems is necessary, in tandem with priority for food security and increased self-reliance, concerted R and D on rainfed agriculture, pro-poor community-based activities, enhancement of C sequestration and reduce emissions of GHGs, application of systems perspectives , increased investments in agricultural productivity, and promotion of public-private sector partnerships to address revitalised agricultural development.

Keywords: Agroforestry; Silvopastoral systems; Food security; Integration; Carbon sequestration; Impacts; Policy.

Introduction

Asian agriculture is a major sector in Asia, and an important determinant of economic growth and technologically driven transformation. The successful economic development through the Green Revolution of the 1960s and beyond is testimony of this fact. Success in agricultural development is dependent to a very large extent on the efficiency in the use and management of the natural resources (land, crops, animals and water). FAO data [1,2] indicates a contribution of 25 to 43% to the gross domestic product (GDP). Much of this contribution is made by the more fertile irrigated areas which are presently over used. However the rainfed areas which are of lower importance, have potential, are currently underutilised and merit more development attention.

About 43-88 % of the human population depend on agriculture for their livelihoods, of which 12-93% of the people live in rainfed areas and 26-84% of the arable land. Some 5-41% of the agricultural output comes from these areas. Due to low productivity, the shares of total crop and livestock outputs coming from rainfed areas is much lower than the share of the total area under irrigation. Livestock contribute 10 to 45% to the agricultural GDP in the developing world, and can be higher if the values of draught power are included in the calculation. About 43-88% of the human population depends on agriculture for their livelihoods, of which 12- 93% of the people live in rainfed areas and 26-84% of the arable land. Some 5-41% of the agricultural output comes from these areas. Due to low productivity, the shares of total crop and livestock outputs coming from rainfed areas is much lower than the share of the total area under irrigation.

South East Asia is a major agricultural sector with such major planted crops as rice, maize, cassava, coconut oil palm and natural rubber. It is a major supplier of grains and industrial products, being for example the largest producer of palm oil and natural rubber. The sector is central to the efficient use of the natural resources, and the emerging challenges, and is directly concerned with to the following key issues:-

- Availability, management and use of the natural resources (land, crops, animals and water) that is consistent with maximising agricultural growth and productivity to the extent possible
- Enhancing food security
- Reducing hunger, poverty and the vulnerability complex
- Stability of human livelihoods and households
- Development of adaptation and mitigation options to cope the climate change, and
- Application of integrated systems perspectives to cope with climate change.

Despite the importance of agriculture, the sector is one of general neglect and does not appear to be high on the priority for national development. This is reflected in lower growth in production of rice, wheat and staples, and inability of the production resources to match the expanding human requirements such as in foods of animal origin due to rapid population growth rates.

Concerning animal production, there is increased justification for improved production systems to accelerate the output of foods

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of animal origin in most countries in South East Asia. This is directly linked to the fact that current outputs of meat and milk from ruminants are relatively low, as are the levels of self – sufficiency in these products, which are exacerbated further by increasing imports at high cost. This increased demand is associated with several demand-driven factors and includes inadequate animal protein supplies; rising incomes, which encourage people to diversify their diets in a variety of meats; eggs and dairy products, including the substitution of calories in livestock for low-priced starch calories [3].

Agriculture will be increasingly threatened with potentially damaging effects of anticipated climate change The Asian Development Bank [4] has produced a regional study on South East Asia on the economics of climate change highlighting perspectives on the regional interdependencies of climate change impacts and policies, and pooling of resources to address shared challenges with reference to Indonesia, Philippines, Thailand and Vietnam. The study has indicated that the agricultural dependent economies will contract by as much as 6.7% annually. The economic cost according to the report would be 2.2% of GDP by 2010 if only the impact on markets is considered, 5.7% if health costs and biodiversity losses are factored in, and 6.7% if losses from climate-related disasters are also included. The latter far exceeds the projected cost globally of climate change, estimated at 2.6% of GDP each year to the end of the century.

Associated with integrated natural resource management (NRM) is the interdependence of agriculture and the poverty complex, involving several millions of poor people, The majority of these rural poor rely and indeed survive because of the reliance on agriculture. An estimated 60% of the working population and generating 25% of the region`s GDP are involved with agriculture. ESCAP [5] has estimated that agriculture alone can lift the estimated 641 million people out of poverty, and that a 1% increase in agricultural productivity would lead to a 0.37% drop in poverty in the Asia - Pacific region It was clear that further progress was limited without necessary intervention and the infusions of new technologies.

Asian Farming Systems

Asian agriculture is characterised by mixed or integrated farming systems and is the backbone of the use of available natural resources. It is typified by a variety of systems in the various AEZs, involvement of the diversity of crops and animals, mainly small farm systems, small farmers and poor people [6]. Mixed farming systems are synonymous with crop-animal systems, are varied and integrated with cropping in various ways. Both ruminants and non-ruminants are involved, and the choice of one or more species is dependent on overriding influence of preference, market dictates, potential to generate income, contribution to crop cultivation and livelihoods. Much will depend on the extent of the functional contribution of animals.

It is pertinent to note that in Asia, mixed farming provided 90% of the milk, 77% of the ruminant meat, 47% of pork and poultry meat, and 31% of the eggs. Past growth trends suggest [7] that mixed farming systems grew half as fast (2.2% per year) compared to industrial systems (4.3% per year), and three times as fast as that of pastoral systems (0.7% per year). The data suggests that ruminant production in mixed farming systems will continue to be important in the future.

In this context it is important to be clear about the terms integration and integrated systems. Integration involves various components, namely crops, animals, land and water. Integrated systems refer to approaches that link the components to economic, social and ecological perspectives. The process is holistic, interactive, multidisciplinary 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 [8]. 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 [9,10]. 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 eg. 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 eg. Oil palm–chickens integration (Malaysia)

Ruminant production systems

Associated with mixed farming systems are ruminant production systems involving buffaloes, cattle, goats and sheep.Four categories are identifiable:-

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

• Systems integrated with tree cropping.

From the standpoint of agroforestry and silvopastoral systems, the fourth system intergrating tree crops and ruminants is the most important.

Agrofoestry and Silvopastoral systems

Agroforestry, silvopastoral systems, and agropastoral systems are variously practiced, involving integration with ruminants [3]. These systems are underestimated, but are being increasingly recognised.- Although tree crops are more commonly grown in the uplands, they are also as in oil palm cultivation, increasingly using up valuable arable land in lowland situations.

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

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

Agropastoral systems: integrates crops, animals and trees.

The benefits of these systems due to synergistic interactions of the system components is illustrated in Figure 1, involving the oil palm as an example. In agroforestry, the various options e.g. planting leguminous trees improves the system to mutual advantage. With silvopastoral systems, stratification of the production system enables not only increased meat production, but also savings in the use of weedicides , increased soil fertility due to the retun of dung and urine and increased yield of fresh fruit bunches. In both cases carbon sequestration can be enhanced.

Advances in Research and Development on Silvopasyotal Systems

In recent years, there has been increasing interest in silvopstoral systems. This is stimulated by inadequate arable land, expanding area under tree crops, increased availability of feeds from tree crops e.g. oil palm, and opportunities for economic value addition resulting from the synergistic interactions between the tree crop and ruminants, greater total contribution. and environmental sustainability.

In this context, there have been significant advances in the understanding of the methodologies used, crop-animal-soil interactions, and resultant benefits in integrated systems with ruminants and tree crops. The main areas in which research has been undertaken include:-

1. Characterisation of environmental conditions within plantations.

2. Measurements of forage availability and quality, as well as seasonality of production.

3. Assessment of the availability of crop residues agro-industrial by-products (AIBP), evaluation of nutritive value and use.

4. Evaluation and selection of grasses and legumes for environmental adaptation and increased herbage production.

5. Measurements of animal performance under different nutritional and management regimes.

6. Measurements of soil compaction and tree damage resulting from the introduction of ruminants

7. Measurements of tree crop yields in integrated systems.

8. Management of animals under tree crops, and

9. Analyses of the economic benefits of integrated systems.

The first four areas are the most studied [11], and the remaining five items merit more attention. Future research and development efforts, backed by increased investments must therefore give increased emphasis to the last five areas. Long term animal production data for the different ruminant species are needed, as also information on the effects of grazing management and socio-economic analyses. These

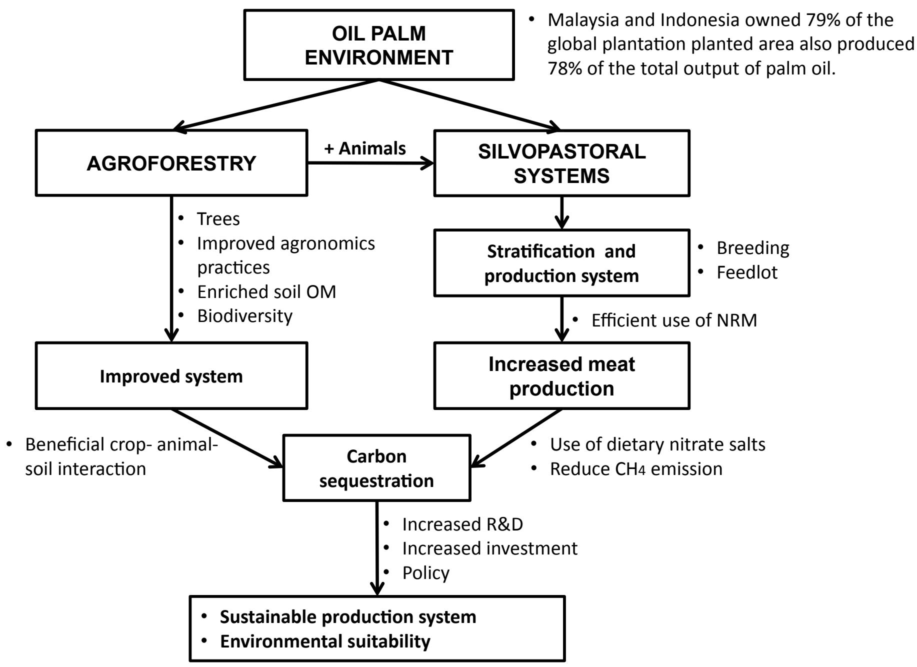

Figure 1: Agroforestry and silvopastoral systems potential and carbon sequestration.

analyses are essential for presenting a convincing case for the wider adoption of the systems. The overall conclusion is that much more work is required in developing methodologies for the process of integrating ruminant species with tree crops, as well as studies on the nature (positive and negative), extent and impact of crop and animal interactions on environmental indicators.

Types of Ruminant- Tree Crop Interactions

There are many benefits of crop-animal- soil interactions [12]. Table 1 gives an indication of the nature of crop- animal interactions in ruminant in oil palm systems. The interactions can be positive or negative, depending on the type of livestock and trees, age of trees, and management systems. Among ruminants, cattle and sheep are well suited to integration with tree crops such as coconuts and oil palm. Sheep are more suited for integration with rubber where light transmission is less and therefore biomass production. Goats are more selective n their feeding habits because they are browsers [10], and are therefore only more suited when both browse and forages are available in agroforestry and silvopastoral systems.

Economic Benefits

A review of the existing information in 21 ccase studies concerning the economic benefits due to positive crop- animal- soil interactions [6] gave the following results with reference to the use of cattle:-

Increased animal production and income

This arises from increased productivity and meat offtakes

NO.	CROP PRODUCTION	ANIMAL PRODUCTION
1.	The natural herbage between inter-rows of oil palms provides a variety of feeds (grasses, legumes and shrubs) which can be used by ruminants. The average availability is 600 kg DM/ha.	Buffaloes and cattle are used extensively for haulage and transportation of products such as fresh fruit bunches.
2.	The oil palm crop also provides many principal feeds (oil palm fronds and tree trunks) and by-products feeds (palm press fibre, palm oil mill effluent and palm kernel cake), all of which can be used by ruminants.	Animals grazing the herb-age control weeds. There are reduced weeding costs (16 – 40%).
3.	The crops also provide valuable shade for animals, which for imported cattle significantly reduces heat stress.	Ruminants and non-ruminants produce manure and urine for the maintenance and improve-ment of soil fertility.
4.		The effective utilisation of the feeds from the oil palm gives valuable animal products such as meat, milk and eggs.
5.		Animals provide an entry point for the introduction of improved grasses (e.g. Guinea grass) and legumes (e.g. Gliricidia) for productivity enhancement in animals with attendant benefits.
6.		The sale of animals, animal products and hiring out of draught animals provide cash for the purchase of fertilizers and pesticides.
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Table 1: Main crop- animal interactions in integrated systems with oil palm.

Increased yield of FFB and income

By about 30 % with measures of between 0.49–3.52mt/ ha/yr.

Savings in weeding costs

By about 47- 60 %, equivalent to 21–62 R/ha/yr.

Internal rate of return

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

Carbon Sequestration and Greenhouse Gases

Mention needs to be made about the potential importance of carbon sequestration. This is an area that has not been addressed in Malaysia concerns carbon sequestration, which is defined as the complex and manure, the expanding land areas under oil palm provide good opportunities for carbon sequestration through more widespread use of grasses and tree legumes, and improved forage management practices, with resultant decreased carbon atmospheric emissions and global warming.

Pretty et al. [13] has calculated that in mixed farming systems, the carbon sequestered per hectare was 0.32tC/ha/yr. The practical implication of this is that agronomic practices need to enhance these carbon sinks through enrichment of soil organic matter and the forage biomass under the oil palm.

Associated with above is the issue of greenhouse gas emissions (GHG), mainly CH_4, N_2O and CO_2 and their effects on climate change or global warming. Improved grass- legume pastures to feed grazing ruminants will have the beneficial effect of enhancing carbon sequestration and releasing more O_2 into the atmosphere. The ADB [4] has recently reported that mitigation can potentially sequester carbon by $3.04tCO_2$/ha.yr, reduce CH_4 emission by $0.02tCO_2$-eq /ha/yr, and reduce N_2O emissions by 0.02-2, $30tCO_2$-eq/ha/yr. On the other hand, the presence of grazing ruminants will mean emissions of more CH_4 into the atmosphere, and their possible effects. In Brazil, Zebu cattle grazing tropical pastures produced a larger methane loss of 27g/kg compared to either Holstein or Nellore cattle fed sorghum silage-concentrate diets that averaged 22g/kg. Holstein or Nellore cattle on Bracharia or Panicum pastures consuming sorghum had methane losses that were close to the temperate forage-based diet of 20g /kg [14].

In response to possible effects on climate change, mitigation efforts have therefore concentrated on ways of reducing the CH_4 emissions in which a wide range of strategies to include enhanced feed quality, supplemental lipids, tannins, protozoal inhibitors with varying success [15]. Of these, strategies to reduce GHGs have largely focused on methanogen inhibitors and substrate levels, rather than at the feed quantity and quality end.

Methane emissions by ruminants from enteric fermentation and manure is a continuing concern. To reiterate, more widespread use of high quality grass-legumes and tree legumes, and improved forage management practices is an important option More recently, it has been reported that fermentable nitrogen requirements of ruminants on diets based on low protein cellulosic materials can be met from nitrate salts [16] and this potentially reduces methane production to minimal levels [17]. Trinh et al. [16] demonstrated that with adaptation, young goats given a diet of straw, tree foliage and molasses grew faster with nitrate as the fermentable N source as compared with urea.

There is a growing body of consistent research results from

Australia , Canada and Vietnam which suggest that the fermentable nitrogen requirements of ruminants on diets based on low protein cellulosic materials can be met from nitrate salts [16] and this potentially reduces methane production to minimal levels [17]. Trinh et al. [16] demonstrated that with adaptation, young goats given a diet of straw, tree foliage and molasses grew faster with nitrate as the fermentable N source as compared with urea Further studies from the same group have shown that nitrate can be used as a fermentable N source for beef cattle fed treated straw [18].

In Australia, a recent study [19], involved sheep being fed with oat hay and either potassium nitrate or urea (5.4 g N/kg hay), first in metabolism cages and then in respirations chambers. Methane production was reduced by feeding nitrate instead of urea but there were no effect on feed intake, DM digestibility or microbial protein synthesis in addition van Zijderveld et al. [20] have shown a 50% reduction in methane production by sheep fed nitrate with sulphate in a corn silage - based diet. The same group have shown persistent reduction of 16% methane in dairy cows supplemented with nitrate (see van Zijderveld et al. [21] quoted by Hulshof et al. [22]) and a 32% reduction in methane production in beef cattle in Brazil when 2.2 % nitrate replacing urea in a sugar cane /concentrate- based diet [22]. This is a major step forward in ruminant nutrition and production.

Further studies from the same group have shown that nitrate can be used as a fermentable N source for beef cattle fed treated straw [18].

Practice	Relative Mitigation Potential (unit of production)	Challenges/Barriers (policy, poverty, knowledge, extension)	Opportunities (feasibility, cost effectiveness, synergy with adaptation)	Opportunities (feasibility, cost effectiveness, synergy with adaptation)
Cropland management • agronomy • nutrient management • tillage/residue management • water management	Potential to sequester soil carbon by 0.55-1.14 tCO_2/ha/year. Potential to reduce N_2O emissions by 0.02-0.07 tCO_2-eq/ha per year.	This option could be costly to implement and would need considerable effort to transfer, diffuse, and deploy. Also, some measures may challenge existing traditional practices.	Use of improved varieties with reduced reliance on fertilizers and other inputs provides opportunity for better economic returns. Reduced tillage will reduce the use of fossil fuel thus lower CO_2 emissions from energy use.	Increases productivity (food security); improves soil, water, and air quality; promotes water and energy conservation; and supports biodiversity and wildlife habitat.
Rice management	In continuously flooded rice fields, potential to reduce CH_4 emission by 7-63% (with organic amendment) and 9-80% (with no organic amendment).	The benefit may be offset by the increase of N_2O emissions and the practice may be constrained by water supply.	More effective rice straw management to reduce management to reduce CH_4 emissions (e.g., as a biofuel).	Promotes productivity (food security) and conservation of other biomes. Also enhances water quality.
Agroforestry, set-aside, land use change	Potential to sequester carbon by 0.70-3.04 tCO_2/ha per year; reduce CH_4 emission by 0.02 tCO_2-eq/ha per year; and reduce N_2O emission by 0.02-2.30 tCO_2-eq/ha per year.	Cropland conversion reduces areas intended for food production. Also, the fate of harvested wood products would need to be accounted for.	Harvest from trees (fuelwood) could be used for bioenergy; additional returns to farmers. Set-aside is usually an option only on surplus agricultural land or on croplands of marginal productivity.	This practice promotes biodiversity and wildlife habitats; energy conservation; and, in some cases, poverty reduction. Improves the quality of soil, water and air; promotes water conservation; supports biodiversity, wildlife habitats, and conservation of other biomes.
Grassland management • Grazing management • Fertilization • Fire	Potential to sequester carbon by 0.11-1.50 tCO_2/ha per year.	Nutrient management and irrigation might increase the use of energy; introduction of species might have an ecological impact.	Improves productivity.	This measure increases productivity (food security); improves soil quality, promotes biodiversity and wildlife habitats; and enhances aesthetic/amenity value.
Peatland management and restoration of organic soils	Potential to sequester carbon by 7.33-139.33 tCO_2/ha per year; and reduce N_2O emission by 0.05-0.28 tCO_2-eq/ha per year.	Need better knowledge of the processes involved to avoid double counting.	Avoiding row crops and tubers; avoiding deep ploughing; and maintaining a shallower table are strategies to be explored.	Improves soil quality and aesthetic/amenity value; promotes biodiversity, wildlife habitats, and energy conservation.
Restoration of degraded lands	Potential to sequester carbon by 3.45 tCO_2/ha per year.	Where this practice involves higher nitrogen application, the benefit of carbon sequestration may be partly offset by higher N2O emissions.		Increases productivity (food security); improves soil and water quality and aesthetic and amenity value; and supports biodiversity, wildlife habitats, and conservation of other biomes.
Bioenergy (soils only)	Potential to sequester carbon by 0.70 tCO_2/ha per year; and reduce N_2O emission by 0.02 tCO2-eq/ha per year.	Competition for other land uses and impact on agro-ecosystem services such as food production, biodiversity, and soil moisture conservation.	Technical potential for biomass; technological developments in converting biomass to energy.	Promotes energy conversion.
Livestock management feeding practices	Improved feeding can reduce CH_4 emissions from enteric fermentation by 1-22% for dairy cattle; 1-14% for beef cattle; 4-10% for dairy buffalo, and 2-5% for non-dairy buffalo.	The effect varies depending on management of animals, i.e., whether confined animals or grazing animals.	The measure depends on soil and climatic conditions, especially when dealing with grazing animals.	Reduced pressure on natural resources (such as soils, vegetation, and water) allow a higher level of sustainability.
Manure management	Up to 90% of CH_4 emitted can be captured and combusted, 10-35% of CH_4 can be reduced by composting, and 2-50% of N_2O emission can be reduced through improved soil application.	Lack of incentives for the broad application of this measure would be a challenge.	Applicable to all waste management systems particularly swine production.	Fewer odors and less environmental pollution.

Table 2: Mitigation options in agriculture in South East Asia.

In a recent study [19], sheep were fed oat hay and either potassium nitrate or urea (5.4 g N/kg hay), first in metabolism cages and then in respirations chambers. Methane production was reduced by feeding nitrate instead of urea but there were no effect on feed intake, DM digestibility or microbial protein synthesis in addition van Zijderveld et al. [20] have shown a 50% reduction in methane production by sheep fed nitrate with sulphate in a corn silage - based diet. The same group have shown persistent reduction of 16% methane in dairy cows supplemented with nitrate (see van Zijderveld et al. [21] quoted by Hulshof et al. [22]) and a 32% reduction in methane production in beef cattle in Brazil when 2.2% nitrate replacing urea in a sugar cane / concentrate based diet [22]. This is a major step forward in ruminant nutrition and production.

Much more understanding is necessary of the relative GHG emissions from improved grass- legume pastures, including the O_2 under oil palm trees compared to grazing ruminants. If the emissions are in favour of the former especially in respect of more O_2 into the atmosphere, the case for integrated systems and sustainable agriculture becomes even stronger. In practice, strategies will need to be developed that can have a balance between the two types of emissions which is consistent with minimal effects on climate change. The answers to many of the interrelated and complex issues remain largely unknown and justify the need for more vigorous research and development.

Mitigation

Concerning mitigation draws attention is drawn toto the excellent information reported in the ADB [4] report. The principal strategy in biological terms relates to greenhouse gas (GHG) emissions in the agricultural sector and includes the following:-

- Reducing fertiliser-related emissions
- Reducing CH 4 emissions from rice paddies
- Reducing emissions from land use change
- Sequestering C in agro-ecosystems, and
- Producing fossil fuel substitutes.

Table 2 summarises details of the mitigation options reported by Smith et al. (2007) in South East Asia. The information relates type of practice, relative mitigation potential, challenges, opportunities, and co-benefits and contribution to sustainable development. The types of practices identified include cropland management; rice management ; agroforestry, set aside, land use change; grassland management; peat land management; restoration of degraded lands; bioenergy; livestock management feeding practices; and manure management.

The highlights of the ADB [4] study are reflected in the following:-

- Estimates exist, though limited, on the range of economic mitigation potential of agricultural practices in South East Asia.
- South East Asia has the highest technical mitigation potential to reduce GHG emissions from agriculture than any other region.
- South East Asia`s vast area of croplands, through cropland management, could be an important channel to sequester C in soils.
- As a major world rice producer, South East Asia can contribute to a reduction of CH_4 emissions while ensuring food security, and
- Other potential mitigation options could boost agricultural production, help reduce poverty, while at the same time help stabilise GHGs.

Potential Production and Environmental Sustainbility

Considered together, the following key potential benefits provide major opportunities and challenges for production and environmental sustainability. Their realisation is dependent on a combination of policy support , greater awareness and understanding of the benefits of integration and efficiency in NRM , institutional commitment , and increased resource use can be brought to bear on expanded integrated systems in the future :-

- Increased productivity from ruminants, mainly meat.
- Value addition to the oil palm crop, and higher palm oil output.
- Improved forages and forage management in oil palm plantations can promote carbon sequestration and reduced possibilities of climate change.
- Enhance carbon sinks and enriched soil organic matter, and
- Demonstrable sustainable agriculture.

Constraints to Integration

Given the very low adoption of integrating ruminants with oil palm, it is relevant to ask what the reasons for this situation are. The reasons are many and are associated with the following:-

- Poor awareness of the potential of integrated systems eg. oil palm and ruminants
- Resistance by the crop- oriented plantation sector
- Inadequate technology application
- High prices for crude palm oil
- Unattractive investment climate
- Weak inter-agency collaboration, and
- Absence of policies to encourage integrated systems.

Overcoming the Challenges and Constraints

There exist a number of opportunities to address the challenges and constraints with the primary purpose of more vigorously promoting and expanding afroforestry and silvopastoral systems. The key aspects of this strategy are as follows:-

1) Need for a definition of a coherent and clear policy to support development

2) An awareness campaign on their value through such approaches as publications, meetings, media and announcements.

3) Increased interdisciplinary collaboration in R and D to ensure improved use of resources, more rapid progress and impacts.

4) Determine appropriate adaptation and mitigation measures to combat the threats effects of climate chang

5) Promote increased participation by the private sector and major stakeholders

6) Encourage increased investments in silvopastoral systems, and

7) Provide a stimulus package of incentives in necessary to promote the systems. These can include inter alia provision of animals, tax breaks for allocation of land, tax exemptions, and interest free loans.

Policy Requirements

The task of stimulating waning agriculture .enhanced productivity, food security and environmental sustainability in the face of climate change provide major challenges for R and D. These need to be supported by policy requirements appropriate for agriculture and are reflected in the following:-

• Affirmation of official policy to address waning agriculture, its revitalisation, integrated NRM and the effects of climate change.

• Priority for food security and increased self-reliance without compromising the environment.

• Priority for concerted R and D on rainfed agriculture and small farm systems.

• Priority for pro-poor community-based activities that can adapt to climate change.

• Promotion of ways and means to enhance C sequestration and reduce emissions of GHG e.g. development of silvopastoral systems.

• Building R and D capacity and application of systems perspectives to deal with climate change.

• Increase investments in agriculture to promote greater engagement and productivity, and

• Promote public-private sector partnerships to address agricultural development in the context of climate change.

In addition to the above proposals, it is also pertinent to draw attention to the policy recommendations by the ADB [4] for mitigation and adaptation for the agriculture and land use sectors in South East Asia.

Conclusions

Agroforestry and silvopastoral systems are potentially very important, but are underestimated in South East Asia. The inclusion of animals has the twin advantages of increasing the supplies of animal proteins and also value addition in the tree crop e.g.oil palm. The benefits of integration are considerable and are further highlighted in several economic impacts. A combination of clear policy, increased technology application and intensive production systems can accelerate the adoption of the systems and demonstrable environmental sustainability. These aspects constitute the challenges for the future.

References

1. FAO (Food and Agriculture Organisation) (1996) FAO AGROSTAT 1995, FAO, Rome, Italy.
2. FAO (Food and Agriculture Organisation) (1997) FAO Prod Year book, Italy.
3. Devendra C (2007a) Perspectives on animal production systems in Asia. Livestock Sci 106:1-18.
4. ADB (2009) The economics of climate change in South East Asia: a regional review. Asian Development Bank, Manila, Philippines.
5. ESCAP (2008) Economic and social survey of Asia and the Pacific 2008. Sustaining growth and sharing prosperity, Bangkok, Thailand.
6. Devendra C (2007b) Small farm systems to feed hungry Asia. Outlk on Agric 36: 7-20.
7. Steinfeld H (1998) Livestock production in the Asia and Pacific region: Current status, issues and trends. Wrld Anim Rev (FAO) 90: 14-21.
8. Edwards P, Pullin RSV, Gartner JA (1988) Research and education for the development of crop livestock-fish farming systems in the tropics. ICLARM Studies and Rev. Manla, Phiuppines.
9. Devendra C (1995) Mixed farming and intensification of animal production systems in Asia. Proc. ILRI/FAO Roundtable on livestock development in low income countries, International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia 133-144.
10. Devendra C (1996) Overview of integrated animals-crops-fish production systems: achievements and future potential. Proc Symp on integrated systems of Anim. Prod. in the Asian Region, Tokyo, Japan.
11. Wong CC, Samiah MN (1998) Integrasi ternakan ruminant dengan tanaman utama, Malaysian Agricultural Research and Development Institute (MARDI), Serdang, Malaysia.
12. Devendra C, Thomas D (2002) Crop – animal interactions in mixed farming systems in Asia. Agric Systems 7: 27-40.
13. Pretty JN, Noble IR, Bossio D, Dixon J, Hine RE, et al. (2006) Resource-conserving agriculture increases yields in developing countries. Environ Sci and Technol 40: 1114-1119.
14. Lima MA, Primavasi O, Dermachi JJ, Manella M, Frighetto RT (2004) Inventory improvements for methne emissions from ruminants in Brazil, Rpt. to the Environment Protection Agency (EPA), USA.
15. Johnson DF, Poungchompu O, Wanapat M (2005) Greenhouse gas production from livestock production systems. Proc. Int. Conf. on Livestock-Crop Systems to Meet the Challenges of Globalisation. Khon Kaen, Thailand 1: 36-47.
16. Hao TP, Quang DH, Preston TR, Leng RA (2009) Nitrate as a fermentable nitrogen supplement for goats fed forage based diets low in true protein. Livestock Res for Rural Dev 21.
17. Leng RA (2008) The potential of feeding nitrate to reduce enteric methane production in ruminants. A Report to The Department of Climate Change. Commonwealth Government of Australia. Canberra, ACT. Australia.
18. Ngoc AN, Hue KT, Khang DN, Preston TR (2010) Effect of calcium nitrate as NPN source on growth performance and methane emissions of goats fed sugar cane supplemented with cassava foliage. Proc MEKARN Conf 2010, Livestock Production, climate change and resource depletion.
19. Nolan JV, Hegarty RS, Hegarty J, Godwin IR, Woodgate R (2010) Effects of dietary nitrate on fermentation, methane production and digesta kinetics in sheep. Anim Prod Sci 50: 81-86.
20. van Zijderveld SM, Gerrits WJ, Apajalahti JA, Newbold JR, Dijkstra J, et al. (2010) Nitrate and sulfate: effective alternative hydrogen sinks for mitigation of ruminal methane production in sheep. J Dairy Sci 93: 5856-5866.
21. van Zijderveld SM, Dijkstra J, Gerrits WJJ, Newbold JR, Perdok HB (2010b), Dietary nitrate persistently reduces enteric methane production in lactating dairy cows. In: greenhouse gases and animal agriculture conference October 3-8, 2010 Banff, Canada.
22. Hulshof RBA, Berndt A, Demarchi JJAA, Gerrits WJJ, Perdok HB (2010) Dietary nitrate supplementation reduces methane emission in beef cattle fed sugarcane-based diets. Conf. Greenhouse gases and animal agriculture conference October 3-8, 2010 Banff, Canada (Mimeograph).
23. Devendra C (2007) Integrated tree-crops ruminant systems: expanding the research and development frontiers in the oil palm. In: Proc. Workshop on integrated tree crops- ruminant systems (ITCRS)/ Assessment of status and opportunities in Malaysia, Kuala Lumpur, Academy of Science Malaysia.
24. Devendra C (2009) Intensification of integrated oil palm–ruminant systems: enhancing increased productivity and sustainability in South East Asia. Outlk on Agric 38: 71-82.
25. Haji Basir Ismail, Tan Sri, Dato Seri (2005) Land Agricultural Policy: a mismatch. Malaysian Palm Oil Board, Kuala Lumpur, Malaysia.
26. Watson RI, Noble IR, Ravindranath B, Verado DJ, Dokken DJ (2000) Intergovernmental Panel on Climate Change (IPCC), Special report on land use change and forestry, IPCC Secretariat, Geneva, Switzerland (Mimeograph).