ESAP CHAPTER 2

HISTORY AND IMPACT OF AKST WITHIN ESAP

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Key Messages

1. **The application of AKST has enabled increased crop production, especially of the staple grains, rice, wheat and maize, during the last 50 years at a greater rate than population thus improving overall food security in the region**. The increase, achieved mostly in intensive irrigated systems, has not translated, however, into complete availability of food. Food insecurity, poverty and malnutrition remain widespread (or id it in pockets? If so where?) in many countries, especially in rural areas. ? How many underfed details?

2. **The rain fed production systems that represent the greater part of the agricultural resource base for the largest number of rural poor across the region have received much less attention in AKST compared to irrigated systems**. (add info. On total rainfed versus irrigated agricultural land). Greater productivity of rainfed systems is required to increase production generally but also to improve the well being of many millions the underfed poor who inhabit these areas. Technologies such as improved cultivars, tillage and sowing techniques, weather prediction already developed within the region (eg Australia) could contribute greatly to increased productivity of large areas in SE Asia (eg the rice-based cropping systems of the rain fed lowlands and uplands) and ? any others where many small-scale farmers continue to rely only on IK and traditional technologies.

3. **ASKT has enabled the development, increased the productivity, and improved the sustainability of aquaculture to supply domestic and export markets for fisheries items and provide employment required to offset the stagnation and decreased productivity of marine and inland fisheries**. Fish production from both inland and marine open waters in most countries are either stagnated or dwindling due to over exploitation, aquatic habitat changes or destruction, excessive withdrawal of surface water and pesticide and industrial pollution. Diversified aquaculture technologies – pond, pen, cage, raft and raceway culture, monoculture, polyculture, integrated aqua-agriculture, etc have developed to suit the region's diversified aquatic environment. Production per unit area has been steadily increasing with the application of improved AKST knowledge. Improved technology includes: liming, fertilization, better water management, balanced feed formulation and better feeding, improved fry quality and improved post-harvest technologies. Fish and shrimp production is intensifying in many countries such that production of 10 MT/ha or greater is common in many countries. Farmers have the option to improve household nutrition and increase income from the

shrinking agricultural. However, increasing culture intensity is often the cause of aquatic pollution and other environmental hazards. Many Governments are showing intense interest in culturing exportable species in the interest of export earning. (Karim's text)

4. **With the exception of the developed economies in the region, funding level on AKST of most ESAP countries has been inadequate and is declining if not outright stagnant despite of its reported high rates of return-on-investments across countries and commodities**. The public sector remains the major source of most of the agricultural R&D expenditures in many ESAP countries due largely to the "public good" character of most AKST products. Whatever little funding the private sector has, have been largely invested into varietal development, crop protection, crop/animal nutrition and in post-harvest processing where intellectual property rights are applicable.

Achievement of food self-sufficiency has apparently resulted in a general decline in the AKST research in the region. But colossal losses of on-farm and post-harvest crop losses as frequently encountered in the region result in huge economic losses to the countries and financial losses to the poor farmers. The situation is greatly responsible for reducing profitability of agriculture. The situation warrants serious attention from the policy makers for undertaking research and investigations to find out ways and means to reduce the undesirable losses in the agriculture sector and make the agricultural activities adequately profitable.

5. **Post-harvest care and processing of food crops, fruit, vegetable, fish and animal products have not received adequate attention in AKST in the region**. Development of appropriate technologies ensuring higher and cost-effective production, environmental social sustainability, prevention or reduction of on-farm and post-harvest losses of crops at various stages along the value chain from the farm to processing plants to consumers, along with certification of the products in respect of food safety and environmental and social sustainability could greatly improve access and profitability of the agricultural products in local and export markets.

6. **In forestry, all countries have developed AKST and associated policies to varying degrees to reduce the impact of logging on forest ecosystems and to support improved forest management and re-afforestation**. Details of application? Further development of AKST is required to support improved forest management for non-timber products and other services, as well as timber production. Plantation forestry has become

a key form of forest management, particularly in China and Japan, but it is not without certain problems. (This will need further discussion).

7. **There is an evident trend of loss of indigenous knowledge in agriculture in many countries**. Details? Cause? Emigration, ?? etc. NGOs and local and communities have become active in recording using and developing IK systems. The contribution of IK to AKST is more recognized, Eg Formal institutions eg CGIAR are paying more attention in participatory plant breeding for diverse conditions. What else?

8. **Plant breeding remains the major method of plant improvement but with increasing application of biotechnology**. Conventional breeding that is more suited to important multi-gene traits such as drought resistance or yield, is now assisted by use of genetic markers ? Which crop species Micropropagation of bananas and ? other technologies or species. Transgenics of rice, maize and cotton, others? are widely planted in China and where else.

9. **Biotechnology including transgenics**. For effectively encountering the future need of food and other commodities and creating employment opportunities for the increasing population, the agriculture sector is to constantly look for new technologies. Greater resistance to diseases and environmental stresses and higher survival and higher production at a cheaper cost will be some of the highly desired qualities of the agricultural crops, including cattle, poultry and fish. Biotechnology may further contribute to the development of the desired qualities in the said crops. However, the short-term and long-term effects of the biotechnological products such as transgenic species on ecology, genetic integrity of the local species and human health will need serious analyses and reviews before making any general prescription on the use of the transgenic species and its variants.

10. **The application of AKST has reduced workload of farmers, including women and children**. The saved time is generally utilized in subsistence and income generating activities. However, the benefit of this additional gained income is not distributed equitably. Women, poor farmers and indigenous people who have low educational background and fewer assets tend to have lesser access to new technologies and benefit least. Equal access to education, information and capacity building are important elements to equalizing the power relations at both the household and community level. The both unpaid and paid contribution of women and children to agricultural production is often not fully recognized or is under valued. As a consequence of this, enough attention

would not get in policies and programs related to AKST. Recognition of their both paid and unpaid contribution would help them receive greater benefit of AKST.

Other possible issues for consideration as Key Messages

- **Animal Industries**
- **Key messages related to AKST relevant to livestock and poultry systems both for small farm systems and commercial level production systems.**
- **Small Farm Systems**
- **Key messages on AKST relevant to the productivity and sustainability of small farm systems.**
- **Mechanization**
- **Key messages on AKST relevant to the impact of mechanization across the region.**
- **Nutrition**
- **AKST has improved human nutrition in terms of availability of staple cereals. Protective nutrients from fruits, vegetables and animal foods continue to be inadequate.**
- **Literature and empirical evidence have shown that impacts of irrigation and access to irrigation on rural poverty and income are mostly positive in the ESAP countries. However, some studies have suggested that increased irrigation is not a sufficient condition for poverty alleviation.**
- **The increased agricultural productivity through application of AKST had considerable tradeoffs on sustainability of soil and water resources, biodiversity and ecological services**. Increased production has been achieved at the expense of the environment, with offsite effects as well as deterioration of the agricultural resource base of soils and water. Improvement of soil fertility and water management, taking into account location-specificity is needed. Biodiversity conservation was not fully integrated in major agricultural production systems. Pest and disease management had contributions to minimize crop losses but new problems emerged.

2.1 History and Impact of AKST within ESAP

The ESAP region is home to about 3.383 billion people or just over half of the world's current population, with China, India and Indonesia currently constituting around 78 per cent of region's inhabitants. Majority – 53% – of this population are still engaged in agriculture related activities, predominantly as smallholders, relying on it primarily for family sustenance, livelihood, income and other socio-cultural functions. .

Agriculture is traditionally an important sector in the national economy in a majority of the countries in the region. As of 2005, ESAP produces more than 80% of the world's supply of coconut, vegetables, jute, sweet potato and rice. In addition, it also provides more than half of the world's supply of tea, tobacco and peanut while at the same time accounting for more than 25% of the global source of melons, sugarcane, white potato, cassava, millet, maize and wheat. The region is also home to 30% of the world's livestock species. However, the share of agriculture in GDP has been declining continuously since the second world war, especially during the last three decades or so. With the exception of the few developed countries, the majority of the ESAP countries' economy remains strongly agrarian. Small land holdings and diversified farming systems are a common feature of the rural society in the region. The small farm size has limited the potential of employment and income earning from the agricultural sector. Rural to urban migration, multiple occupations of the labors, and the diversifications of the rural economy have been a trend evident in many countries in the region. During the last two to three decades, remarkable progresses in the rural economic development have taken place in many countries, particularly China and India. The number of rural population living under poverty has reduced substantially, although the reduction rates vary largely across the countries. Technology features as one of the major keys to development. The extent to which it can be instrumental to poverty alleviation depends on three major factors, namely the sources of technology, dissemination of technology and distribution of benefits from its adoption (Khunkitti, 2002). However, as ESAP countries move towards rapid industrialization and globalization, the emerging multiple roles of agriculture is becoming much more apparent and prominent as different economies strive for a more sustainable development.

The population growth and the economic development have generated ever-greater demand for food. Increasing population combined with limited land area (2,167 million ha),with a large fraction as inhospitable terrain has resulted in a low proportion of agricultural area per capita – average of 0.64 ha/person and concentration of most of the people on less than half of the total available land area, resulting in severe and increasing pressure on natural resources (land, water, flora & fauna) in many places with notable exception of Australia and New Zealand. Increasing food production with the limited land and water resources presents a taunting challenge to the governments and the people in the region. Intensification of production in almost all agricultural sub-sectors, e.g., crop farming, animal husbandry, fishery and forestry, with support of modern AKST has been seen in the most of the countries.

ESAP is the origin of the 'green revolution', which is characterized by application of high yielding varieties together with the expansion of irrigation and provision of chemical fertilizers. The significant improvement in crop yields enable a large increase in total food production. However, evidence in some countries, such as India, suggested that the sole augmentation of total food production has not always benefited the poor in terms of increasing income and improving food security.

The ESAP countries currently face new challenges for agricultural production. In many areas the extent of land available for cultivation has reached its limits. A growing number of areas, particularly parts of China and India, have been enduring water stress, threatening the sustainability of food production on irrigated land. Water has been increasingly becoming a limiting factor to agricultural extension. At the same time, problem of land degradation, environmental pollution, loss of biodiversity, lack of investment in agriculture R&D are affecting the agricultural potential of the region. Consequently, in recent years, many ESAP countries have become net food importers.

A good understanding of the past trends in the agricultural sector and the impacts of AKST in the ESAP region is useful for the search of appropriate AKST to meet the challenges concerning sustainable agricultural development and food security. This chapter provides a review of history and impacts of AKST with a time horizon of the last 50 years. The focus, however, will be on the last two-three decades because of the better data availability and the substantial role of AKST in agricultural production and rural development during the period. The review is conducted from three aspects.

In the ESAP region, the past half a century has witnessed a remarkable economic growth in majority of the countries, leading to significant raises in income and thus demand for greater quantity and better quality food and other agricultural products. Along with economic growth, there has been a rapid population increase, from around 1.6 billion in 1960 to 3.4 billion in 2004. During this period, agricultural knowledge, science, and technology (AKST) have experienced an unprecedented progress which has been the foundation underlying the continuous growth of agricultural production to meet the increasing demand.

This chapter provides an assessment of trends in AKST and the impact on agricultural production and sustainable development goals in the ESAP region, particularly the last 50 years. Recognizing the complexity in agricultural production systems and great diversity across the countries in the region, the assessment covers the prevailing production systems with a focus on practices of small farmers. Emphasis is given to modern AKST that are of significance for the whole region. Indigenous knowledge systems and some local specific practices that have profound implications for sustainable agricultural and social development are also examined.

Modern AKST, particularly those associated with the Green Revolution, have been developed primarily with aims at increasing agricultural products in quantity and quality, and enhancing the resilience to various physical stresses. However, impacts of AKST are often not neutral to different groups of people in a society and across countries. Natural endowments, socio-economic conditions, culture and tradition all have influences on the innovation and adoption of AKST. Some AKST are applicable mainly to large and commercial farming systems, whereas some others are more suitable for small and subsistence farmers to adopt. This assessment will provide a balanced view of the impact of AKST on the sustainable development goals, including ecosystem services and human well being, in the ESAP countries.

2.2 Trends in AKST and its Impacts on Current Production Systems

2.2.1 Crops and cropping systems

There is great diversity in agricultural production practices and major farming systems (see Chapter 2.4) across the ESAP region in terms of natural endowments, farm sizes and cultivation practices. The farmers have selected and adapted available technologies to their needs in response to threats and opportunities from changing environmental and economic conditions. Farmers' adoption of technologies had increased the wheat yield. The Australian wheat industry, as exemplified by this analysis of yield trends in the State of Victoria, had already passed through two phases of technological development before 1950. The subsequent phases (Connor 2004) where mean yields for each year from the outset around 1840 are related to key changes in the application of technology. The high yields present a best crop performance in this region where in many years yields are substantially reduced by low rainfall. The most important technology that contributed to the high yield included the breeding of a succession of disease (rust)-resistant wheat cultivars increasingly better adapted the short growing season and the harsh environmental conditions. This technological contribution that commenced with germplasm imported from India and Europe. Herbicides and pesticides became available and increasingly precise fertilization, including micro-nutrients, especially for pasture legumes (Mo, Mn), became possible. Weed and disease control and management of N fertility by mineralization rather than from moisture conservation contributed to yield. Wheat yields rose to a new plateau, around 2 t/ha by the 1980s. The cycle of legume-based pasture and wheat, known as 'clover ley farming' is justifiably an Australian invention (Smith 2000). Farmers in the current require technological and economic skills to manage increasingly complex cropping systems. High yields are possible only in the years of greater than average rainfall. In low rainfall years, the focus of management must be to minimize costs. Cropping is now not a matter of applying established cropping sequences but rather adjusting crop type and management to likely seasonal and economic conditions. Nitrogen fertilization is a good case in point. The objective is to gain yield benefit in years of high potential and avoid the possibility of yield loss due to haying off (Van Herwaarden et al. 1998) in years of low rainfall.

Furthermore, a new phenomenon has been observed in ESAP countries. Although aggregate agricultural area per capita have been steadily declining, its rate of decline has been gradual, particularly in North Asia, the Oceanic states and the Southeast Asian counties. This may be due to the reduction in agricultural population by migration of rural people to urban areas in search for better employment opportunities in the industry or service sectors.

Mechanization is taking place in many aspects of crop production. On the whole, farm management practices – from planting to harvesting and post-harvesting - in Australia, New Zealand and Japan are mechanized whereas in the other ESAP countries, the type of management and thus extent of mechanization varies according to the farming practices. Farmers in the developed countries in the region tend to own the machines they use. In other countries, the trend has been for individual machine owners to provide paid services to the farmers without machines. .– this is not true as they work in what is called a Satoyama and thus do have collective actions and the high cost of production is because of high labour costs and standard of living, so suggest deleting the sentence. In South Korea, a rich farmer can buy one kind of machine and work for many farmers as a service contractor. This is very effective in terms of reduction in production cost. Other countries like Malaysia, Thailand and Vietnam are already following suit. In case of rice, many practices have been mechanized such as plowing, sowing, water pumping, harvesting, and drying. Combined harvesters have been introduced successfully in Malaysia, and Thailand. Now Vietnam has also started to introduce combined harvester.

Intensification of crop production supported by expansion of irrigation and usage of chemical fertilizers and pesticides has been a trend evident in many countries. The inputs used for crops increased over time in developing countries. Fertilizers and pesticides usage for crops in Japan, Australia, South Korea are already high. However in a number of developing countries like China, Thailand, Vietnam, Malaysia, India and others the usage of these inputs has also been increasing.

Growth in food production within ESAP, particularly cereals, during the last four decades has been higher than the world average, both in aggregate and in per capita terms. And, in spite of a doubling of their population from 1.58 billion in 1961 to 3.23 billion person in 2000, average per capita food consumption in ESAP increased by nearly 50 percent from 100 kg in 1961 to 149 kg in 2003. The highest rates of increment are under Oceanic states (from 8.9 kg/person to 37 kg/person) and South East Asian countries (from 202 kg/person to 293 kg/person). The proportion of undernourished people also declined by at least 15% from 918 million in 1970 down to 780 million in 1995 and 702 million in 2002 (quoted in subchapter 2.3). However, rising food supplies does not necessarily mean that everyone has access to enough food. The abundance of food suggested by these trends masks the fact that hundreds of millions of people still do not have enough food to eat. Improved technology, especially for small-scale farmers, has hastened poverty reduction through increased crop yields and higher incomes. But their access to technology has been hampered by gaps in infrastructure, seed and input markets, extension systems and very often, their ability to afford those inputs. Market, institutional and policy failures have likewise exacerbated the problem. A great deal needs to be done to alleviate small farmers' constraints to technology access and profitable use. Technologies that build on and complement local knowledge tend to be particularly effective in meeting the needs of subsistence farmers in marginal environments. This subchapter desperately needs references, please put them in. Also need to be sensible about use of figures so have deleted decimal places – no data on food consumption can surely claim to be accurate to 100g on food intake

2.2.1.1 Role of irrigation in agriculture.

Irrigation is one of the most widely used agricultural technologies in the ESAP region. In many countries, irrigation has a long history which is closely linked to the history of rice cultivation. The rapid population growth, limited arable land resources, and the continuous increase in food demand during the past 50 years or so have driven an unprecedented expansion of irrigated areas. Advances of modern technologies in dam construction, flow regulation, and pumping equipments have provided the necessary means to harness more water for expanding irrigation.

Between 1961 and 2003, irrigated areas, using surface water in the ESAP region as a whole more than doubled, with an annual growth rate of around 2.6%. In China and India, the pace surpassed the average of the rest of the EASP countries (Figure 2.1). However, it is noticeable that since the late 1990s, the expansion of irrigated areas slowed down in the region. India and China even appeared to decrease slightly. By 2003, about 28% of the cultivated land in the region had been brought under irrigation.

[Insert Figure 2.1: Changes in irrigated areas in ESAP, 1961-2003]

Variations are substantial across countries in terms of the pace of irrigation expansion and the share of irrigated areas in total cropland (Table 2.1). Irrigated areas in Bangladesh, Japan, Korea DPR account for over 50% of their total cultivated land. The figures are only between 1-8% in Australia, New Zealand, Malaysia, Mongolia, Cambodia and Fiji. Japan is the only country in the region that had experienced a decline in irrigated areas. This is closely related to the shrinkage of paddy rice area, which nearly halved during the period 1961-2003 (FAO, FAOSTAT, 2006).

[Insert Table 2.1: Changes in irrigated areas by country, 1961-2003]

Irrigation provides a powerful management tool against the vagaries of rainfall and makes it economically attractive to grow high-yield varieties and to apply adequate plant fertilizers as well as pest control and other inputs, thus giving room for a boost in yields. Irrigation was an important component in the Green Revolution package prevalent in the 1960s through 1980s. The availability of irrigation is crucial for achieving stable and high yields, and increasing total food production. The crop yield on irrigated land is typically double the yield on rainfed land. A national survey in China shows that wheat yield on irrigated land is between 2-5 times of that on rainfed land (IIASA, 2000). Irrigated agriculture has played and will continue to play an important role in the national strategy for food security in many ESAP countries.

Apart from boosting yield, availability of irrigation also enables a more intensive use of land. Double and triple cropping was able to expand to the areas where the rainy season is only long enough for one crop a year. The high yield and the increased intensity of land use have resulted in a much larger proportion of food production on irrigated land than its share in total cultivated land. For the region as a whole, about 60 percent of the food production is from irrigated land, as composed to about 28% of irrigated land in total cropland. In China and India, irrigated areas produce about 70 percent and 50 percent of the national total food production, respectively (Lipton and Litchfield, 2003).

The role of groundwater irrigation. Surface irrigation is traditionally the most widespread irrigation practices in the ESAP region. However, the past 50 years have seen a rapid expansion of groundwater irrigation. As electricity became more widespread, and pumping and well-drilling technologies improved, groundwater as a source of irrigation has become increasingly important particularly in arid and semi-arid areas. By the mid 1990s, half of China’s irrigation water came from wells (Brown, 1994). In India, about 60% of the irrigated areas rely on groundwater (Figure 2.2).

[Insert Figure 2.2: Sources of irrigation, India]

[Insert Figure 2.3: Number of agricultural pumps per hundred rural households in China, 1985-2005]

Groundwater offers a primary buffer against the vagaries of climate and surface water delivery. Because groundwater is on demand and just-in-time, crop water productivity is often higher than that in the surface irrigation condition. Evidence from some locations in India showed that yield on groundwater irrigated areas is 2-3 tons/hectare higher than the canal irrigation (Shah et al. 2001; Lipton and Litchfield, 2003).

The proliferation of groundwater wells owes a lot to the divisibility of groundwater technology, such as treadle pumps, at affordable prices. Low-cost pumps helped fuel the groundwater boom mostly with private investment from farmers. Groundwater is available to anyone who can afford a pump in groundwater rich areas. It has been a boon to small farmers, even to the poor ones. In China, the number of groundwater pumps owned by individual farm households increased by more than 12 fold between 1985 and 2005 (Figure 2.3). However, in some parts the contamination of ground water and/or decrease in the water table means that this expansion may not be able to continue in the futurev(Giordano and Vilholth, 2007).

2.2.1.2 ASKT in improving irrigation water use efficiency

Water use efficiency is generally low in irrigation. Various water saving technologies have been developed and promoted to improve the water use efficiency in irrigation.

Water requirement ratio and water productivity. Irrigation water withdrawal normally far exceeds the consumptive use of irrigation. This means that only a part of agricultural water withdrawals are used in the production of food and other agricultural commodities. The rest of the water does not reach the crop plants because it evaporates or infiltrates during conduction, evaporates from the soil in the field, or is used by non-productive growth such as weeds.

The ratio between the irrigation water requirement and the actual irrigation water withdrawal is traditionally referred to as ‘irrigation efficiency’. However, the use of the words ‘irrigation efficiency’ is currently subject to debate. This is because part of the unused water can be used further down-streams in the irrigation schemes, or can flow back to the river or contribute to the recharge of aquifers. For this reason, the term ‘water requirement ratio’ has been used by FAO to replace irrigation efficiency to avoid confusion (FAO, AQUASTAT, 2006).

[Insert Figure 2.4: Water requirement ratios in the ESAP countries]

The water requirement ratios are around 30 percent in a majority of the ESAP countries (Figure 2.4). A large percentage of the water withdrawal for irrigation has not been used by crops on that location. Part of the ‘lost’ water may be used by downstream users. Nevertheless, evidence in many countries suggests that real loss of water to evaporation is large. With increasing demand for water from all economic sectors, water resources have become scarce at the local and even national level in many countries. Improving water use efficiency in irrigation by introducing water saving technologies, and drought resistant varieties has been promoted as one of the ways to meet the challenge of water scarcity.

Recent years have seen a paradigm shift of irrigation technologies from solely pursuing water saving to improving water productivity. In its broadest sense, improving agricultural water productivity generally refers to increasing crop yield or economic value per unit of water delivered or depleted. It can also be extended to include non-crop food such as fish or livestock. By improving productivity it is possible to reduce the need for investments in new water withdrawals. It is particularly important to the incomes and food security of the poor people.

A distinction can be made between those measures that increase water productivity by increasing crop yield for a given evapotranspiration or diversion, and those that reduce the water diversion requirements. Molden and Fraiture (2004) pointed out that in the former case (e.g., increase in crop yields through varietal improvement) savings at the plant and field level are realized at the system and basin level. In the latter case (e.g., system of rice intensification) increase in water productivity at system and basin level is not assured because the excess water diversion in a location may be available to downstream users. Whether increased water productivity at plant and field level translates into increased productivity at system and basin level needs to be determined by water balance studies. Unfortunately, such studies are rare so far and the understanding of water balance and interactions at plant, field, system and river basin levels is far from adequate. The lack of understanding tends to cause confusion in the selection of appropriate measures to improve water productivity.

Water saving technologies. In the surface irrigation systems, flood irrigation has been a dominant method in the ESAP countries. Given the generally low water requirement ratio, there is a large room for reducing the water diversion to the field. Commonly used water saving technologies include furrow and border irrigation, mulch, and terracing. Empirical evidences have suggested that water saving potential is high at the irrigation system level. In Ningxia Autonomous Region in China, official statistics show that irrigation water withdrawal from the

Yellow River decreased from 8.9 billion m3 to 6.7 billion m3 between 1998 and 2004, whereas irrigated area increased from 387 thousand hectares to 406 thousand hectares, due to the implementation of various water saving measures. reference

Application of more advanced water saving technologies, such as sprinklers and micro irrigation, has been seen in the region, but in a rather small scale. In Japan, areas applying the sprinkler irrigation and micro irrigation were about 9.5% of the total irrigated areas in the late 1990s. In India, the figure was merely 1.5%. Mongolia is the only country where sprinkler irrigation represents a significant part of the area under irrigation as large schemes were systematically equipped with sprinkler irrigation in the 1980s (FAO, 1999). In China, areas equipped with sprinklers, drip irrigation and low pressure pipes accounted for about 10% of the total irrigated areas in 2004 (National Bureau of Statistics of China, 2006). In other countries, national data for the application of irrigation techniques are generally not available.

Drip irrigation. Drip irrigation was developed commercially in Israel. By the mid-1970s, farmers in some ESAP countries, such as Australia, New Zealand were starting using the method. Drip irrigation is especially effective in arid and drought prone areas where water is scarce. It does not entail salt accumulation in the root zone, thus causes little soil erosion. Compared to furrow or sprinkler irrigation, drip systems cuts water use by 30-60% (Postel, 1996). In India, it was reported that the crop yields using drip irrigation are about 10-30% higher than that using surface irrigation (postel, 1999). Despite the efficiency in water use, drip irrigation is only a very small percentage of the total irrigated areas. In Australia, the percentage is about 7.8%. In China and India, it is below 0.1%. The relatively large initial investment required for the equipment is one of the main constraints to its application in developing countries. The use of drip irrigation is primarily to irrigate high value, horticultural crops.

Supplemental irrigation. Supplemental irrigation is essentially the application of a limited amount of irrigation at critical times. It can substantially improve yield and water productivity in arid and semi-arid environments. Studies have shown that in dry areas, supplemental irrigation can boost productivity of irrigation water by 10 to 20 percent (Oweis and Hachum 2003). Technologies for supplemental irrigation range from farm ponds to micro-irrigation with shallow groundwater pumped with treadle pumps (Barker and Molle, 2004). Supplemental irrigation can prevent total crop failure and stabilize and improve crop yields. However, it requires more comprehensive knowledge and skills of crop management. Inclusion of risk-reducing information with weather forecasts is also an integral part of such a comprehensive strategy.

Rainwater harvesting for irrigation. By and large, rainwater harvesting is defined as the collection of runoff for human use. The collection processes involve various techniques such as the collection of water from rooftops and the land surface, as well as within water courses. Rainwater harvesting as a means to retain water in situ has been seen in some semi-arid areas in the ESAP region. Rainwater harvesting not only provides more water for the crop but can also add to groundwater recharge and help to reduce soil erosion. Water is collected from the local catchment and either relying on storage within the soil profile or local storage behind bunds or ponds and other structures for use during dry periods. Rainwater harvesting has shown a considerable potential to deal with the water constraints in semi-arid areas because it can supply limited irrigation at the key stages of crop growth by using rainwater stored. A number of cases in China and India have shown a significant increase in crop productivity through rainwater harvesting. In Gansu province in China, for example, yields of maize and wheat on the experimental sites increased by over 50% (Liu et al., 2005).

Rainwater harvesting technologies are simple to install and operate for local people. It is convenient in the sense that it provides water at the point of consumption, and family members have full control of their own systems, reducing operation and maintenance problems. Disadvantages of rainwater harvesting technologies are mainly related to the limited supply and uncertainty of rainfall. In addition, numerous small-scale water-harvesting and storage systems in a basin could have similar effects on river flows and aquatic ecosystems as a large dam and canal irrigation. For example, along the Yellow River, water conservation structures (bunds, gully-plugging) have been effective in encouraging agriculture and in reducing erosion, but there is evidence that these practices have reduced river discharge (Zhu et al., 2003).

Rainfed agriculture and ‘green water’ management. Compared with irrigated agriculture, the rainfed systems have so far been given low attention in most of the ESAP countries. The Green Revolution has largely bypassed rainfed agriculture systems. The paucity of technology in rainfed areas partly relates to conscious decisions by authorities to concentrate research/extension efforts in irrigated areas because of the perception that these areas are likely to yield a greater return on investment. Until now, the potential to improve non-irrigated yields is restricted where rainfall is subject to large seasonal and inter-annual variations. Genetic engineering has not yet delivered high-yield drought-resistant varieties. For most crop plants, currently drought resistance is associated with low yields.

Among many constraints that limit the potential of rainfed agriculture, unreliable rainfall and thus water available to crops probably is the biggest. Water stress at the flowering stage of maize can reduce yield by 60%, even if water is adequate during the rest of the crop season (Molden and

Frauiture, 2004). In order to increase the production on rainfed areas, it is important to produce high yielding lines with resistance to major stresses, including unreliable rainfall patterns, pests and diseases. Recent years have seen increased efforts in life sciences focusing especially on traits such as drought tolerance and resistances to a wide variety of pests and diseases.

Apart from irrigation water productivity, improving water productivity of rainfed systems through improved land management techniques and agricultural production systems have received growing attention. This has been generally referred to as ‘green (soil) water management’. In some areas, conservation agriculture practices such as minimum or zero tillage have proven to be effective in improving soil moisture, thus the crop yields in rainfed land (Hatibu and Rockström, 2005). In addition, use of terracing, contouring and micro-basins are also important measures in maximizing rainfall infiltration into the soil to increase yields.

No-till/conservation agriculture (NT/CA): NT/CA maintains and improves crop yields and resilience against drought and other hazards, while at the same time protecting and stimulating the biological functioning of the soil. The essential features of NT/CA are the minimal soil disturbance and the maintenance of a permanent cover of live or dead vegetal material on the soil surface. It protects the soil against erosion and water loss by runoff or evaporation. A major impediment to the successful introduction of NT/CA is the required complex management skills. In many ESAP countries, any production system that includes crop rotation is more complex as it calls for coherent management over more than one or two crop seasons. Farmers will need to understand the new system and the reasons for the various procedures, and adapt them to their specific needs and conditions to balance crop rotation with market requirements.

Rainfed systems in Australia: Amid the general negligence of rainfed agriculture in many ESAP countries, the progress in rainfed wheat production system in Australia is rather noticeable. Major practices include an introduction of a fallow year into the cropping sequence to conserve water from one year to the next and, application of phosphorous fertilizer. Other innovations include the breeding of a succession of disease-resistant wheat cultivars that are better adapted to the short growing season and the harsh environmental conditions. Mean yields responded by a significant rise. However, high yields are possible only in the years of greater than average rainfall. Crop type and management, therefore, need to be adjusted to likely seasonal and economic conditions (Connor 2004). Large annual fluctuation in production is a distinctive feature of the rainfed wheat system and indeed all other rainfed crops in Australia. It is reported that the severe drought in 2006 reduced its wheat production by 61% over the previous year. Other dryland crops, such as Barley and Sorghum, fell by about the same percentage.

Some other examples in Australia rainfed agriculture include the systems of the dryland farming of sheep and wheat, the establishment and maintenance of tropical pastures and leguminous forages, the management of grazing animals in the pastoral zone, and the development and use of improved, clover-based pastures in rainfed and irrigated areas of temperate Australia. These examples have been cited as models which might be used in the agricultural development of similar ecological zones in Africa, South America and Asia. However, because of the different nature and socio-economic conditions and institutional setting, the farming systems developed specifically for Australia may not always suit other countries. This may be particularly so for many ESAP countries where land holding is very small and subsistence farming is predominant. Nevertheless, many of the specialist and technological aspects of Australian farming systems are transferable and some supporting policies, attitudes and infrastructures of proven value in Australia also have wider application. Any references?

Potential of rainfed agriculture. Studies on potential yields in rainfed and irrigated systems at the country level are few in number. According to the results from a project on Global Agro-Ecological Zones (GAEZ) led by the International Institute for Applied Science Analysis (IIASA) in Austria, large differences exist between attainable yields on rainfed and irrigated land for each crop. For example, the estimated results for India show that the maximum attainable yields with the existing varieties and under the optimal field management for rainfed and irrigated wheat are 1786kg/ha and 4352kg/ha, respectively. Potential yields of rainfed and irrigated rice are 2516kg7ha and 8161kg/ha, respectively. In both cases, yields on rainfed land are only about 1/3 of those on irrigated land.

There are different views on the potential of rainfed systems. Many (name some as references) argue that evidence exists for great potential and poverty reduction from new approaches to enhancing rainfed agricultural systems. New pro-poor small-scale, low-cost approaches such as treadle pumps, water bags, and water harvesting are proving to be the key to unlocking rainfed potential and reducing poverty on marginal rainfed lands. Although crop yields seem low considering the amounts of land, water, labour and capita required, new technologies are available to help farmers predict uncertain variables such as rainfall. This improved predictability can help increase the contribution of rainfed agriculture.

Skeptics (name some as references), on the other hand, point out that rainfed agriculture has been the focus of research for many years, that ideas have been in place for a long time, yet gains are not forthcoming. Thus rainfed systems do not hold as much promise as claimed. Dependence on approaches to enhancing rainfed agriculture involves high risk due to climate variability, particularly affecting small and poor farmers. As poor people often live in semi-arid agricultural environments where the ability to cope with weather variation is very low, and the failure of crop often means starvation or even death. A study in three semi-arid watersheds in India by Bouma and Scott (2006) showed that large scale investments in soil and water conservation did not have a significant impact on dryland yields, at least not under prolonged conditions of drought.

Integrated green and blue water management. Integrated rainwater and irrigation water management with innovation and application of suitable technologies has been increasingly emphasized and seen as a promising way to deal with water-food challenges. Given the difficulties in obtaining additional water for irrigation and the constraint of unreliable water supply in rainfed systems, agricultural water management has seen a trend of shift from focusing on pure rainfed or fully irrigated systems to emphasizing on the practices in the middle of the water continuum where soil conservation, supplemental irrigation, drip irrigation, ground and surface irrigation are intricately connected NEED REFS (Figure 2.5). (I think you might need a box on blue and green water just so people can understand even the terms)

[Insert Figure 2.5: Agricultural water management: A continuum of practices]

Upgrading rainfed systems refers to introducing more conservation practices to store water in soil, and at the same time adding blue water, typically in small systems. In contrast, improving large-scale irrigation requires better managing and using of green water directly from rain. An important dimension is the divisibility of water management technology. Some blue-water-dependent systems serve many people, often requiring public funding. Others are individually managed, such as small groundwater wells and pumps, and can be funded by individuals or communities.

Technologies for the most part of water management on the continuum already exist; the challenge here is tailoring them to local situations and identifying the factors that influence uptake, including the necessary supporting institutions. Tools are also needed to assess the potential environmental impact of large-scale implementation of these small-scale solutions.

2.2.2 Livestock

Millions of rural households in Asia-Pacific countries depend on domesticated animals for food, farm power and income. The region is home to 30 percent of the world's livestock species. Though livestock food products are still not a significant part of the diet in developing Asia-Pacific countries, consumption is growing rapidly. Developing Asian countries now have the world's highest growth rates of production and consumption of food derived from livestock (FAO, 2006).

The dynamic Asian livestock subsector is growing at a rate between 3.5 and 5 percent per annum – more rapid than the crops sector such as cereals, vegetables and pulses – driven partly by increasing population, rising incomes and changes in consumer lifestyles. By the year 2020, it is estimated that intake of animal products will equal or exceed those from crops worldwide in value terms (Ranawana, 2005). Since animal products are expensive to import, most countries planned to meet this rising demand through increased domestic production. Hence, livestock growers in peri-urban areas are increasing production and modifying management systems to respond to this rapid rise in demand. Structural changes are also being led by the growth in urban areas of supermarket vendors of livestock products, intensifying the need to examine opportunities for vertically integrating vulnerable producers. Small-scale producers are not generally a part of the rapid rise in intensive animal production. And yet, more than half of the small-scale farmers in Asia rely on livestock as a major source of income and nutrition (FAO, 2006).

Although most ESAP countries are technically capable of increasing production on meat, milk and eggs, majority face shortages of key feed ingredients particularly corn and soybean meal. As a result, there is a large and burgeoning trade in feed crops worldwide.

On the other hand, the drive by livestock growers to serve urban markets has led to intensive production, with problems of livestock waste, land management and distribution. Thus, there is now greater awareness of the potential for transmission of disease from animals to humans, particularly with the current bird flu (avian influenza) crisis. Such diseases affecting animals and humans can spread rapidly across the region, creating trans-boundary animal disease epidemics. There are also concerns about the rising demand for livestock feed, increased need for veterinary services and training, loss of genetic resources and need for extension of cash-making livestock opportunities for small-scale producers (FAO, 2006).

2.2.3 Status and trends of forestry AKST in ESAP

– note the tables, figures and references are at the end of the text in this file)

Forests cover about 25% of the area across Asia and the Pacific. The Pacific Islands with 65% forest cover and Insular Southeast Asia with 53% cover have the highest proportion of land user forest. Papua New Guinea has the largest rainforest coverage in the Pacific region and accounts for the third largest block of tropical rainforest in the world (Chatterton et al., 2000). South Asia has relatively low forest cover.

Although ESAP contains only about 5 percent of the world's forests, it accounts for an estimated 25 percent of forest loss over the last decade (World Bank Forest and Forestry website). The Philippines has had the highest rates of deforestation followed by Pakistan, Thailand and Malaysia, however, the largest losses have occurred in Indonesia and Myanmar (Waggner. 2001). Between 1990 and 2000 the region experienced considerable decline in forest cover with the greatest decline occurring in Insular South East Asia, followed by Continental South East Asia and the Pacific Islands (Waggener and Lane, 1997). Forests in the South Pacific are being removed at an unsustainable rate. (UNESCAP, 2000).

[Insert Table 2.2: Forest cover change in the Asia-Pacific region 1990-2000]

Population pressure and the resultant conversion to agriculture is perhaps the most important cause of deforestation across the region. While in percentage terms the greatest forest lost has been in the smaller Pacific islands, the forests of Insular and Mainland Southeast Asia have been subjected to the greatest population pressure (Brown and Durst, 2003). Deforestation has frequently been cited as a major contributing cause of erosion, decreased water quality in rivers, sedimentation build up on near shore reefs, flooding and landslides. However, a recent FAO-CIFOR study suggests there is little scientific evidence to confirm a direct relationship between loss of forest cover and large scale flooding events. The study suggests that land degradation and soil erosion, again often associated with deforestation, are actually more directly related to poor land-use practices including overgrazing and litter removal (FAO RAP Publication 2005/03) This is a good example of where you need to do an assessment – You have FAO's conclusion, but are there others that might suggest otherwise in particular terrain, in particular rainfall area? I recall a CIFOR discussion paper that seemed to suggest at least for some parts of Indonesia/Malaysia that deforestation may be the main cause of land slides. Flooding events I can belief but in the previous sentence you mention "erosion, decreased water quality in rivers, sedimentation build up on near shore reefs, flooding and landslides" and the FAO only covers the flooding.

Most countries in the region have well-defined policies, laws and programs aimed at regulating the use of forests and the development of forestry activities, but are they implemented and enforced?. Historically, most ESAP countries have regulated forest management by assigning management responsibilities to government agencies and by attempting to enforce strict controls on forest access. Transient upland populations and traditional tenure systems based on common access to forests have often conflicted with government policy initiatives. I think this is a bit weak as it does not say anything about corruption which you can at least refer to as "weak environmental governance"

Natural forests are not just limited to terrestrial environments. The Asia-Pacific region is also home to greatest concentration of mangroves (Primavera, 2000). Once thought of as coastal wasteland, mangroves have been destroyed at alarming rates for agriculture, aquaculture use and for firewood. It is estimated that up to 50% of mangrove destruction in recent years has been prompted by the desire to create shrimp farms (UN Atlas of the Sea, 2002). Over the last 20-30 years with the help of the UNESCO Mangrove Programme (Vannucci, 1997) and other international initiatives government planners and fisheries experts have become more aware of the many hidden roles that mangroves play as a nursery for many coastal and aquaculture fish species and as a key buffer that reduces the impact of sediment flows on to offshore reefs and as a barrier to protect again storm surge and tsunami events. It is estimated that 90% of all marine organisms spend some portion of their life cycle within mangrove systems (Adeel & Pomery, 2002). Although mangroves have some commonality with open access natural forests in terms of management, this topic is treated under the fisheries subchapter (2.2.4).

Given the varied array of conditions, practices and policies surrounding forestry within the region, any useful discussion of the impact of knowledge, science and technology on this sector must be focused on the following key sub-sectors: 1) natural forest management, 2) plantation forestry, 3) agroforestry, 4) community/social forestry, 5) collection and processing of non-timber forest products (NTFPs), 6) wood processing, 7) forestry research and 8) the impacts of forests on climate change.

2.2.3.1. Natural forest management

Within the Asia-Pacific region there are over 552 million ha of forests, of which 477 million ha are natural forests. However, only about 249 million ha are available and suitable for harvesting (Waggner, 2001). The natural forests throughout ESAP have up until very recently been seen largely as a vast natural source of raw timber to generate export income, however, there is general agreement on the need for a transition from a focus on timber exploitation to an emphasis on management for sustainable multiple use of natural forests (Enters, 1997). In the face of increasing deforestation, many countries across the ESAP region (including China, New Zealand, Philippines, Sri Lanka, Thailand, and Vietnam) have imposed a variety of total, partial, temporary or selective bans on logging in natural and old growth forests. The results of these restrictions have been mixed and a number of case studies have indicated that such bans can have unanticipated impacts on timber supply, forest harvesting, transport, processing and consumption of forest products and forest residents and those who depend on forestry for their livelihoods (Waggner, 2001).

The need for sustainable forest management is clearly recognized throughout ESAP but there are not many examples of effective management practices being implemented on a large scale. In some areas such improved practices as reduced impact logging (RIL), (Dykstra, 2002), and forest and timber certification (TC) (Upton and Bass, 1995) and log tracking systems (Tropical Forest Update, 2006) have been introduced as avenues for more sustainable management. Forest Certification involves the issuance by a third party that an area of forest is managed in accordance with a defined set of standards. Chain of Custody Certification is a process for tracking wood products from a certified forest to the point of sale (Forest and Trade Asia website).

In 2000 there were a total of 33 Forest Management Certificates in Asia and the Pacific (FSC, 2000). Key examples include Malaysia's national Timber Certification Council (MTCC) and Indonesia's Ecolabeling Institute (LEI) (ITTO, 2005). Model Forest Programs have been evaluated in China, Indonesia, Japan, the Philippines, Myanmar and Thailand. (Dykstra, 2002). These technologies and management practices are a response to an increasing demand by consumers for "sustainably sourced products and competitive prices," (Kiekens, 1995). However, it has been noted that the incorporation of social criteria and indicators into forest management and harvest practices has been criticized as being difficult to assess and interpret in the field (Wollenberg and Colfer, 1996). Although there has been no significant impact of timber certification on loss of tropical forests over the last two decades, the application of TC has created greater awareness among forest managers of the need to protect the environment and minimize the loss of biological diversity (Thang, 2003).

In addition to the limited use of a range of technologies to reduce the impact of logging on the environment and the forest soils, governments in the region have put in place a number of policies also designed to both reduce the environmental impact and to increase economic returns. Thailand has a total ban on logging within its borders, The Philippines has banned the export of unprocessed logs and Bhutan has mandated that the country must keep 60 per cent of total land area under forest cover (UNEP, 2005). However, the effectiveness of these laws and plans is often greatly reduced due to limited resources, shortages of skilled staff, political corruption and weak law enforcement. Rather than the introduction of new technologies, the critical issue is the lack of political will in most countries to enforce already existing policies and regulations (Enters, 1997).

Outside of requirements for reforestation, natural forest management is primarily focused on forest harvest techniques designed to minimize the impact on the natural regeneration, ground cover and underlying forest soils. In some places traditional cut and drag systems are being replaced by less environmentally damaging systems. For example, in Malaysia skyline cable systems and helicopter lifting have been used to minimize land degradation from harvesting timber on steep slopes. These and other technologies were originally developed for forestry in temperate areas and can clearly be adapted for use in tropical forests. The real constraint has to do with the fact that most forest harvesting in ESAP is carried out by private companies where the profit motivation is the driving force with respect to management practices. Portable wood chippers are available but currently there are little or no economic incentives for the extraction or on-site processing of harvest waste material. Helicopter logging and cable and skyline yarding systems represent a large capital investment that may not be justified by the value of the timber available, especially if there are no constraints imposed upon the harvester regarding conservation of soil and water or damage to the residual stand. Although cable yarding systems damage soils and understory less than cut and drag systems, they may be more difficult to use in forests that are selectively harvested. As is common in Asia, rather than clear felled, as is common in temperate forests (Friday, 2007).

2.2.3.2. Plantation forestry

Plantation forestry is another form of management found in the region. In 2000, the Asia Pacific Region accounted for 61% of the global distribution of forest plantation. And within ESAP five countries (China, Japan, Indonesia, and Thailand) Harold, you only have 4 countries cited instead of the 5 mentioned earlier) ranked among the world’s top ten plantation countries. Together, these countries account for 55% of the world’s plantation resources and 91% within Asia and the Pacific. (Brown and Durst, 2003) This is a rather new phenomenon with the average age of Asia’s industrial plantations being less than 15 years (FAO, 2001).

[Insert Figure 2.6: Asia-Pacific industrial plantations: total area versus area available for harvesting by sub region]

With diminishing availability of large diameter timber from natural forests in the region, plantation forestry is expected to become the dominant source for wood resources in ESAP. Currently the region accounts for more than 80% of forest plantations systems in the tropics (Enters, 1997). At present, the majority of legally produced industrial wood in the region is sourced from plantation forests. Most plantation forestry in the region can be described as the intensive management of monocultures for the production of a relatively narrow range of products and species; the main species are pines, teak, poplars, acacias and eucalypts (Enders, 1997)

[Insert Table 2.3: Plantation areas by sub-region and species in 2000]

“Due to the extent of plantations in China and their short rotation, majority of Asia’s plantation forest are aged less than 15 years. This is largely the result of a very rapid acceleration in plantation establishment in China, and owing to the short rotation generally used in that country. Japanese plantations tend to be in the older age classes ” (FAO/Rap Publication 2003/22) There is considerable diversity in this sector in terms of ownership, management systems, scale of operation and products. Plantation systems have been established to meet the need for a number of different products including fuel wood, poles, wood chips, furniture wood and various estate crops including rubber, oil palm and coconut. Up until the last 25 years, forest plantations were largely smallholder or government operated. Presently the growing trend is for increasing private sector investment and management of forest plantations in response to an increasing demand for wood for pulp, furniture and particleboard. Smallholder plantations have sprung up to meet this market, e.g. in the Philippines (Garrity and Marcado, 1994 and Pasicolan, et. al, 1997), Nepal (Malla, 1992), Laos (Roder et al., 1995), India (Saxena, 1995) and in Thailand.

The technological innovations in the plantation sector depend on the production objectives (e.g. conservation, fuelwood, fiber, or sawlogs). The technologies and management practices that have been adopted by plantation operators include such things as improved seedling production using polyethrelene bags, centralized nurseries, and thinning and pruning for sawlog production. The introduction of breeding programs and the use of improved planting material from tissue culture is still relatively minor (Enters, 1997). The use of improved trees has been limited to the large commercial plantation operations, particularly in China. Next to no improvement work has been done for the species that are commonly used in the multipurpose small farm operations. Harvesting technologies range from manual to completely mechanized largely in response to rising labor costs and increasing concern to minimize soil disturbance.

Although the reduced species diversity and younger tree age associated with plantation forests provide conditions favorable to the spread of disease and pests, these risks are often compensated by the uniformity of production outputs. In addition to providing raw material for an expanding wood productions industry, plantation forestry is seen by many as a tool to also address a number of environmental objectives such as soil conservation, mitigation of erosion, carbon sequestration, and rehabilitation and protection of habitats for important wild flora and fauna resources.

2.2.3.3 Agroforestry

Agroforestry has come to mean many different things, but in its simplest form it refers to the incorporation and use of trees in farming systems. As such, the focus has been primarily on small- holder systems and the topics have gained widespread attention by government agencies and non-governmental organizations as a key tool to address a range of soil conservation objectives and meet livelihood needs. Because of its potential for increased enhanced food security, poverty reduction, and environmentally sound land management, one of the 15 CGIAR supported international research centers is devoted to research and development initiatives in this area. The World Agroforestry Center (ICRAF) defines agroforestry as “a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversified and sustains production, “(www.worldagroforestrycenter.org.). Agroforestry involves the integration of trees with other crops and enterprises. As such, tree farms and nut plantations that are managed as a monocrop are not considered to be agroforestry, (Beetz, 2002).

A number of different technologies and management practices have been associated with agroforestry including: 1) Alley Cropping, 2) Improved fallow systems, 3) Silvopasture, 4) Windbreaks, and 5) mixed agroforests, including breadfruit based systems in the Pacific Islands, and 6) Riparian Buffer Strips. Sometimes, forest farming for non-timber forest products is included under agroforestry. This system will be addressed as a separate sub-sector.

The technology associated with agroforestry that has received perhaps the widest coverage in the literature and in development projects is alley cropping. This recommendation involves the incorporation of tree hedgerows within crop fields to act as an in-situ fallow and to improve soil fertility through nitrogen fixation (Kang et. al., 1960, Craswell, et. al., 1997). In Asia hedgerows have been promoted on slopping fields primarily to reduce soil run off from erosion (Garrity, 1986). While there are some significant success stories of the positive impacts of alley cropping, particularly in alfisols that are not deficient in phosphorous (Sanchez, 1995), alley cropping has not been as widely adopted as promoted. There are examples of it working well as a component of SALT (Sloping Agricultural Land Technology) program in the Southern Philippines. However, for the most part, alley cropping has not been widely accepted within ESAP because it was designed primarily as an approach for conservation rather than as a technique to meet the immediate needs of farmers. It is labor intensive, particularly when applied in upland areas, and has, in most cases not resulted in sufficiently high economic returns to justify the added labor. Tree-crop competition for light, water, and nutrients has also led to the failure of many alley-cropping systems to outperform traditional cropping systems (Sanchez, 1995).

However, when focused on production for the expanding wood products industry, agroforestry may generate increased interest in the future. In places like Malaysia, small farmers are already growing rubber for its wood, rather than latex. Rubberwood, previously seen as trash, now is in demand as a light colored wood for furniture making.

One key assessment sure you want to use this word and not analysis? suggests that: 1) Agroforestry will not be widely adopted for forest rehabilitation as long as farmers do not have secure land tenure and use rights, 2) Resource poor farmers will only receive marginal benefit from an expansion of agroforestry activities, and 3) Future agroforestry efforts are likely to focus not on the extensively managed home gardens but rather on more intensively managed small-scale plantations that produce only one or two products for commercial use (Enters, 1997) including coffee, cacao, and tea. Other viable objectives include the production of fodder crops, living fences and shade trees. Roger Leakey, (formerly of ICRAF) and J.B. Friday feel that the future of agroforestry in much of the developing world lies in intensifying and commercializing the management of traditional home garden forests. Such options will need the support of researchers and community development practitioners in the selection of desirable trees, propagating technologies and standardizing products and developing markets. Given the less than optimal adoption of researcher-designed systems, modernizing traditional systems that build upon existing farmer knowledge may be a more successful strategy (Friday, 2007). I would reword this paragraph to say there are two different views and then present them and you would have to at least provide some sort of a document list for Leakey and Friday's belief. If you can say under what conditions one has succeeded rather than other that would be great. Remember this has to be what has happened in the past.

2.2.3.4. Community/social forestry and farm forestry

In the narrowest perspective, community forestry denotes the governance and management of forest resources by communities for both commercial and non-commercial purposes. At the core of community forestry is the recognition that communities living adjacent to or in forests have rights to extract resources and to manage the forests to support their livelihood needs and traditional knowledge of how to manage these forests. As such, community forestry has been the focus of policy and training initiatives rather than technological interventions. In places like India and Papua New Guinea where customary and/or village ownership of forest areas is recognized, community forestry programs have focused on educating villagers to become better stewards of their forest lands. As a development strategy it has come to be seen by many governments in the region as a way of involving rural communities in the active protection and management of forests (Nurse and Mall, 2005). In practice, the term Community Forestry is often used interchangeably with Social Forestry to refer to a broad range of activities that involve local people in various forestry activities ranging from the managing of wood lots and the growing of trees as a cash crop to the household level processing of forest products (FAO 1978, referenced in Casson, 1997).

The initial focus in the early 1970s was on meeting the fuel and income needs of the rural poor and reducing deforestation and desertification. Over the last 40 years the concept has expanded to be seen as an important tools for community empowerment (Hidayat, 1998, Poffenberger, 1990) and Community–based Forest Management (CBFM) and Participatory Conservation in the Philippines (Utting, 2000). Other variations on the same concept include such things as Joint Forest Management (JFM) in India (Fisher, 2000), Village Forestry in Lao PDR and Collective Forest Management (CFM) in China (Gilmour, et. al, 2004). One of the model examples of community-based forest management comes from Nepal where there are over 12,000 recognized Forest User Groups (FUGs) managing more than a million ha of forest. As such, its primary purposes have been to generate local-level support for the sustainable management of natural resources. One of the many challenges to community management is the need to resolve issues related to forest tenure, ownership, user-rights and common access. Another key issue that has yet to be effectively addressed by community forestry initiatives is how can such locally-focused participatory approaches be scaled up to have an impact across landscapes (Nurse and Malla, 2005).

An area that has received little if any, with respect to the development and transfer of improved technologies is Farm Forestry. This is defined as the growing trees on privately owned agricultural land, waste land and degraded forests (FAO, 1988). There is an important perceptional difference between social forestry and farm forestry. While planners of social forestry projects have emphasized the subsistence return to farmers in terms of fuel wood and fodder, farmers have placed their priorities on the contribution of trees to cash income (Blair, 1986, cited in FAO, 1998). Given farmer emphasis on cash income areas where farm forestry has been most successful are regions where small farm cultivators have a long history of producing for the market where the cash returns from trees and agricultural crops can be easily seen. (Chum, 1986, cited in FAO, 1998, and Pasicolan et. al, 1997). This is also a more common practice in “developed” countries such as Australia with farm forests providing a range of ecosystem services similar to agroforestry and community based forestry, but to individual farmers.

2.2.3.5. Non-timber forest products

Managing forests for the production and collection of non-timber forest products (NTFPs) has received very little attention other than as one component of agroforestry and as a so-called traditional agroforesty practice. Part of the problem lies in the fact that there is no clear agreement on what constitutes non-timber forest products. The broadest definition would include all biological materials harvested from forests for human use (Davidson-Hunt, et. al, 1999). Factors of scale, mode of harvesting and market are also factors that distinguish NTFPs for other forest wood products. NTFPs are usually harvested by individuals, households or small groups and they are usually marketed directly by the harvester or through small processing operators. It is also sometimes useful to distinguish non-timber products from other forest products and services such as aesthetic values and tourism values.

Although there is no exhaustive list of what constitutes NTFPs the term is generally used to refer to forest plants and animals that are used for food, beverages, forage, medicine and fiber. Although large numbers of rural households use NTFPs to augment their agricultural and subsistence incomes, little data exists related to number of people employed and the value of NFTP outputs across the region. NTFPs are collected for many different reasons. Some are consumed by those who collect them while others are traded and processed before reaching international markets. In Nepal, collectors of NTFPs in the Middle Hills can either sell their collected goods to local traders or roadhead traders who export the goods to India and elsewhere (Edwards, 1994)

In response to strong market demands, some NTFPs such as rattan in Malaysia, are being domesticated and grown in plantations specifically for commercial use. Such practices meet consumer needs without further depletion of natural forest stocks, (Poh, 1994.) Other forest products that were formerly grown in the wild and that are now grown commercially include some tropical fruits, cocoa, coffee, tea, cardamom, cinnamon, cashew and pepper.
While domestication of some species is likely to expand to meet growing market demand, for many rural and upland residents the collection of NTFPs will remain a significant contribution to subsistence farming. In principle, the harvesting of NTFPs from natural forest habitats should be sustainable, however, in practices this is often not the case, particularly where changes in land tenure, hydropower projects and logging roads have given easy outside populations easy access to NTFPs in remote areas (Enders, 1997)

2.2.3.6. Wood processing

The wood processing capacity in the region has increased significantly over the past 30 years with concentration in the most developed countries of the region and those with the largest populations including Japan, Australia, New Zealand, Korea, Malaysia, Indonesia, China and India. The major products from natural forests and plantation forestry in ESAP are sawn timber, wood and wood-based panels, woodchips, pulp for paper production and other products such as poles and railroad ties.

Wood processing is the area that has received the greatest impact from technological improvements. Most of the improvements have come through the adaptation of technologies from industrial countries including such things as medium density fiberboard (MDF). Most of the modern processing machinery has been imported from Europe (Enters, 1997). With the decreasing availability of large diameter logs, milling and processing equipment has been adapted for processing of smaller diameter trees from forest plantations. A case in point is MSF production, which emerged as a response to shortages in raw material and the newly developed ability to utilize formerly untapped resources to produce a plywood type product. MDF and other similar products have become price competitive alternatives to plywood, particleboard and hardboard. (Adhar, 1996 cited in Enters, 1997) Within the ESAP region, Malaysia is the number one exporter of veneer sheets and Indonesia is the number one exporter of plywood followed by Malaysia.

[Insert Table 2.4: Value of forest commodities exported by major Asia-Pacific exporting countries – 2001 (US$ million)]

With many governments now banning or severely restricting the export of unprocessed logs there has been a demand for efficient processing systems and the conversion of sawn timber into particle and other wood-based panels. Likewise, as noted earlier, some woods that were previously considered to have little or no value such as rubber wood are now being processed for the furniture industry. Largely as the result of research and development work at the Forest Research Institute of Malaysia, a major market has been developed for the use of rubber wood in furniture and panel products (Hong, 1995). The processing technologies used for the processing of rubber wood have also been applied to oil palm stems and research is currently looking at the possible use of oil palm fiber as an ingredient in various wood-based boards as well as for pulp and chipboard. Compared to natural wood and plywood products, composite, defect-free fiberboards can be easily produced in large uniform sizes (Yayah et al., 1995). When the supply of natural fiber begins to dwindle the panel processing industry will likely see the introduction of non-wood fibers. The major non-wood fiber processing facilities are located in China and India (Enters, 1997).

Sawmilling technologies exist but will require appropriate incentives for processors to upgrade their facilities (Wadsmorth, 1995, p.23). Wood processing is in direct response to wood product consumption that is driven primarily by marketing rather than the introduction of new technologies. In addition to the growing market for wood-based panels, improved technologies for pulping introduction of the improved pulping systems should be matched with stricter regulations of effluent discharge (Wilson, 1995).

2.2.3.7. Forestry research in Asia and the Pacific

Most of the tropical forests are located in developing countries where the research infrastructure and institutional capacity is generally weak (Dembner, 1994). This deficiency is compounded by the fact that much of the forestry research and technology developed in the temperate areas of the world is transferable to the tropics. Consequently, there is a strong need for the countries of the Asia-Pacific Region to develop their own forest research capabilities.

There are over 120 centers and programs in the ESAP region involved in various aspects of forestry research (Rao, 1994). Current levels of research activity are often insufficient to meet the growing demand for information to support forest management and conservation (Riley, 1994). However, there are some notable success stories including the research by the Forest Research Institute of Malaysia (FRIM) that has transformed such unknown commercial species as rubber wood and oil palm stems into a sustainable multimillion-dollars processing and export industry(Salleh and Wong, 1994). In addition to the 19 full-fledged Forestry Research Institutes in the region there are a number of externally funded forestry research initiatives that have been active in the region since the 1980s. In spite of such efforts, forestry research still suffers from a number of key constraints including: little political support, lack of sufficient funding, minimal linkages between researchers and end users, lack of "research extension" efforts and inadequate library and information services (Rao, 1994).

In addition to the national forestry research organizations two of the CGIAR (Consultative Group on International Agricultural Research) Centers are focused on forestry research and have done considerable work within the ESAP region – The Centre for International Forestry Research (CIFOR) and the International Center for Research in Agroforestry (ICRAF) – see also Chapter 1. CIFOR, located in Bogor, Indonesia, is mandated "to promote the sustained wellbeing of people in developing countries, particularly in the tropics, through collaborative strategic and applied research in forest systems and forestry, and by promoting the adoption of improved technologies and management practices." A key component of the centers work is to increase forestry research in developing countries (Sayer, 1994). CIFOR focuses its work in five major areas. 1) Policy Development; 2) Management and Conservation of Natural Resources; 3) Reforestation of Degraded Lands, 4) Products and Markets, and 5) Research Support and Information. The majority of these efforts are carried out in close collaboration with national forestry research systems.

ICRAF's work is done primarily in the humid and semi-humid tropics and involves knowledge systems for better understanding the major interactions between people, trees, crops and animals that contribute to productive agro-ecosystems. Although based in Kenya, ICRAF, also know as the World Agroforestry Center, has its second major centre in Bogor, Indonesia and outreach operations in China, Lao PDR, the Philippines, Thailand and Vietnam (World Agroforestry, Research Center website. One of ICRAF's priority programs is on the improvement of multipurpose tree species.

One promising area of research is the application of biotechnology in forest tree research. Although a number of techniques including tissue culture, cryopreservation, use of molecular markers, genetic engineering and micropropagation have all been applied to forest improvement in the temperate areas (Haines, 1994) there is little application of these technologies within ESAP except for the use of tissue culture for species within some plantation forestry systems.

2.2.3.8. Forests and climate change

Forests are affected by and contribute to climate change Too basic Next to the burning of fossil fuels, deforestation and forest fires are the most significant contributor to greenhouse gas emissions. Other greenhouses gases, including methane and nitrous oxide are also released in the atmosphere through the burning of biomass, especially forested wetlands/peatlands. However, environmentally sound management of forests can also help to reduce greenhouse gas emissions and contribute to carbon sequestration (Roper, 2001) (this really needs to be replaced by IPCC reports – the Land use, Land use change and forestry report is one such)

[Insert Table 2.5: Principal greenhouse gases

It is estimated that 125 Giga tonnes of carbon are exchanged annually between terrestrial vegetation and soils and the atmosphere and that forests account for around 80% of this exchange (FAO, 2001) – again IPCC figures would make it stronger. Such management practices as reforestation and agroforestry can contribute of increased carbon sequestration. Tropical forests have by far the greatest potential for carbon conservation (Brown, et. al., 1996 – replace with IPCC figures). Managing forests to generate increased carbon sequestration and storage involve activities that minimize deforestation, reduce potential for forest fires, minimizing soil disturbance and expanding forest cover through tree plantations and agroforestry plantings. When natural forests are harvested or burnt, there is a net loss of stored carbon and varying degrees of emission of CO_2 . On the other hand, when fuel wood plantations are replanted after harvesting there will be little or no net emissions because the carbon that is lost will be captured again by photosynthesis in the new plantings (CFAN, 2004, Bolin and Sukumar 2000, IPCC 2000) providing there is no loss of carbon from soils (IPCC 2000).

Given the increasingly recognized role that forests and trees play in climate change a number of international donor agencies have recently partnered with national governments to promote village-level carbon sequestration projects. Two examples include the Forest Resources Management for Carbon Sequestration (FROMACSD) project in Indonesia and the Community-based Natural Resource Management for Carbon Sequestration in East Timor. Both of these efforts are supported by the Canadian Climate Change Development Fund (CFAN, 2004).

2.2.3.9. General trends

Major trends and Issues within ESAP Forestry

Major Trends include:

- Increase in plantation forestry to compensate for dwindling supplies of natural timber
- Increasing experimentation with reduced impact harvesting technologies
- Increased use of wood processing systems that can accommodate smaller diameter logs
- Creation of products from wood previously considered of no commercial value (e.g. rubber wood and oil palm stems).
- Greater potential for use of improved technologies in wood processing than in natural forest management and harvesting

Key Issues include:

- Lack of resources and political will to effectively enforce existing forestry laws and regulations and combat illegal logging.
- Need for more national attention to be given to supporting national forestry research and extension.

2.2.4 Fisheries

Fisheries, an agricultural component of immense importance in many countries, comprise all aquatic animals and plants that are exploited and utilized for commercial purposes either as food, feed, a source of recreation or as raw materials for various industries. It includes fin fish, shellfish, cetaceans, frog, sea-cucumber, seaweeds, etc.

In the ESAP region, fisheries play a vital role in food security supplying valuable animal protein, minerals and vitamins, employment generation, poverty reduction and revenue earning through domestic and export trades. Fish is a part of cultural heritage in many parts of India and Bangladesh, where it plays an important role in matrimonial and some other social customs and celebrations. People utilize all sizes and types of fish and there is very little discard of this valuable aquatic resource. There are two sources of fisheries products: (i) capture of the wild fish, shrimp and other aquatic organisms from the sea and inland open water bodies and (ii) aquaculture either in freshwater or in brackish or marine waters.

Globally, fisheries production during 1950 – 2004 has registered a steady increase with an upward trend of the ESAP contribution (Figure 2.6); the ESAP countries contributed 64% to the total global production in 2004 (FAO, 2007a, 2007b). ESAP fish production increase in the recent years is largely attributed to the significant development of aquaculture. As a result of aquaculture knowledge, science and technology have been constantly generated and refined.

[Insert Figure 2.7: ESAP percent contribution to the global fish production]

[Insert Table 2.6: ESAP place in global fish production (depending on if the greenhouse gas emission is deleted or not)]

Capture fisheries are either stagnated or dwindling in most countries of the ESAP region as well as other regions of the world. Historically, the vast sea, and the inland open waters in the form of lakes, rivers, canals, etc were rich sources of fish. With relatively little efforts, people could harvest plenty of fish from waters close to the shore and meet their demand. They maintained that the sea was an inexhaustible source of food. As the human population increased and the resultant demand for fish enhanced, people gathered more and more knowledge and technology to quickly and safely go further afield in the quest of fish. The modern fishing fleet with cold storages, processing facilities, fish scouting airplanes and highly sophisticated acoustic technology can correctly detect the size and nature of the fish schools in the open sea and at various depths of water. This technology coupled with extremely efficient fishing gear including purse seine and trawl nets made dramatic increase in the marine production. But, unscrupulous applications of the technologies have eventually resulted in over fishing and depletion of the oceans' stocks of fish (FAO-SOFIA, 2006). Despite caution from the scientists, many of the rich marine fishing grounds all over the world and also in the ESAP regions have been excessively exploited for a number of years.

Fish and other fisheries organisms have been heavily exploited not only for direct human consumption as food, but also as industrial raw materials for production of fish meal used as farm animal feed, vitamin oils, soap, isinglass for wine purification, and varieties of other uses. As a result, 8% of the marine fisheries has been depleted, 16% overexploited, and 52% fully exploited; only 21% moderately exploited and only 3% remains underexploited as represented in Figure 2.72 (FAO-SOFIA, 2006). The trend of marine capture production globally and in the ESAP region is given in Figure 2.8 and Table 2.6

[Insert Figure 2.8: Status of marine fisheries exploitation 2004]

The inland lagoons, rivers, canals, flood plains and other open waters are no exception in many countries, (Figure 2.9 and Table 2.7; FAO, 2007a). Effective enforcement of conservation rules, in respect of marine or inland open water fisheries resources, has seldom been possible. Aquatic habitat changes or destruction due to massive construction of embankments for flood control, drainage and irrigation, barraging in the rivers, excessive surface water withdrawal for agricultural or other purposes, aquatic pollution due to agricultural pesticides or indiscriminate release of industrial effluents and unplanned construction of rural roads and culverts obstructing fish movements, etc have all contributed to the destruction of fisheries in different ways.

[Insert Figure 2.9: Trend of global and ESAP marine capture fisheries]

[Insert Figure 2.10: Trend of global and ESAP inland capture fisheries]

[Insert Table 2.7: Trend of global and ESAP marine and inland capture fisheries]

In at least six of the ESAP countries, viz., China, Japan, India, South Korea, Thailand and New Zealand, marine capture production have demonstrated clear declines (Figures 2.10 and 2.11; FAO, 2007b). The total marine capture (27,961,707 MT) of these six countries represents 69% of the total of marine capture (40,491,257 MT) of the entire region.

[Insert Figure 2.11: Marine capture fisheries trends in China and Japan]

[Insert Figure 2.12: Marine capture fisheries trends in India, S. Korea, Thailand and New Zealand]

As opposed to the stagnation or decline in the capture fisheries, aquaculture production has increased at a rapid rate. Significant increase in the global human population, reduced supply of food fish and the high priced exportable aquatic species from the open water and the concomitant increased demand for them domestically and globally stimulated aquaculture practices to quickly develop and flourish. Many rural farmers urgently need income increase from their limited and gradually shrinking agricultural land holdings to meet the minimum necessities of life. Farming various aquatic organisms is a profitable proposition and thus this activity has been rapidly gaining importance for aquatic food production, employment creation, poverty reduction and increased revenue earning through domestic and export trades.

Both Global and ESAP aquaculture production since 1950 have been demonstrating a steady increase but the rise since 1990 has been quite spectacular (see Figure 2.13 (FAO, 2007b).

[Insert Figure 2.13: Global and ESAP aquaculture production trend]
[Insert Table 2.8: Global and ESAP aquaculture production (MT) trend]

World aquaculture production in 1950 was 638,577 MT representing only 3% (Figure 2.13) of the global total fisheries production. Aquaculture production rapidly increased to a massive 59,408,444 MT representing 38% of the global total production from all sources by 2004 (Figure 2.14).

[Insert Figure 2.14: Trend of percent contribution of aquaculture to global total fish production - 1950]
[Insert Figure 2.15: Trend of percent contribution of aquaculture to global total fish production - 2004]

From a level of 343,854 MT in 1950, ESAP aquaculture production escalated to an impressive 53,720,253 MT representing 90% (Figure 2.12) of the global aquaculture production of 59,408,444 MT (Figure-7, Table 2.7) and 54% (Figure 2.15) of 99,844,154 MT of fisheries products that came from all sources in the ESAP region in 2004 (FAO, 2007b).

[Insert Figure 2.16: Aquaculture percent contribution by volume in total ESAP fisheries]

Within the ESAP region, the first seven countries in respect of total aquaculture production by volume (including aquatic plants) in 2004 are China, India, Philippines, Indonesia, Japan, Viet Nam and Thailand. China alone produced 41,661,660 MT accounting for 78%. The next six countries accounted for 17%. All the remaining countries constituted the remainder 5%.

[Insert Table 2.9: Aquaculture production (including aquatic plants) of top seven producer countries of ESAP]

Excluding aquatic plants, the relative positions of the top seven countries somewhat change (Table 2.9). Bangladesh appears in the top seven producing countries. Positions of Thailand and Vietnam improve, while the Philippines disappears from the list. Positions of Indonesia and Japan are degraded.

[Insert Table 2.10: Top seven aquaculture countries in ESAP 2004 (excluding aquatic plants)]

Aquaculture products' value. The value of the ESAP aquaculture products is estimated at nearly US$56 billion (Table 2.10), which is about 80% of the global aquaculture products value. Although the rest of the world produces 10% of the global production by volume, it contributes 20% of the value, indicating that they produce more of higher value items. Within ESAP, China alone accounted for 66% of the total ESAP value; six other top countries when added together with China, exceed 92% of the total ESAP value. (FAO, 2007b)

[Insert Table 2.11: Value of aquaculture products (including aquatic plants) of top seven aquaculture countries]

Fisheries contributions to GDP. In several of the ESAP countries, fisheries substantially contribute to GDP (Table 2.11 -, (APFIC, 2006). Most of the small Pacific island countries, e.g., Kiribati, Marshall Island, Vanuatu, Solomon Island, Micronesia, etc heavily depend on their fisheries for GDP. In many of the major aquaculture countries, contribution of aquaculture towards GDP is more than 50% of the total fisheries contribution. GDP contributions separately for aquaculture and capture fisheries are not available for many countries.

[Insert Table 2.12: Fisheries contribution (%) to GDP]

Employment . The ESAP region is estimated to include 87% of the total global number (total 38 million) of persons engaged in capture and aquaculture production (FAO-SOFIA, 2006). These figures possibly represent only those persons who are full time fishers and aquafarmers. The actual number of persons who provide labour to these sectors at various stages of fishing and aquafarming and at the related ancillary industries, including net making, boat and transport carrier construction, fish processing, feed milling, ice making, trading, etc must be immensely more. Bangladesh alone employs an estimated number of 12 million people in the fishing and aquaculture industry (DOF, 2003). In its shrimp aquaculture sector, an estimated 600,000 persons are employed on full time and part time basis (Karim, 2003). The estimated numbers of employments in some selected ESAP countries are given in Table 2.13 (NACA, 2006)

[Insert Table 2.13: Estimated employments in aquaculture sector in selected ESAP countries]

Per capita fish consumption. In some of the countries, fish is the major source of animal protein (FAO-SOFIA, 2006): Cambodia (75%), Bangladesh (63%), Philippines (52%), China (32%). It is not easy to get reliable data on per capita fish consumption since fisheries products are variously utilized. Some part of it is also exported. But, some countries import fish to augment supply to the people.Fish consumption figures as reported by FAO (FAO FISHSTAT plus, 2004) are presented in Table 2.14

[Insert Table 2.14: Fish consumption in kilograms per capita in selected ESAP countries]

In most of the countries in Asia, aquaculture started in the freshwater ecosystem for the culture mainly of carp and carp related species. But, in Indonesia and the Philippines aquaculture began in the brackishwater ecosystem mainly for the culture of milkfish in the tidal flats. In the beginning, aquaculture was simple and entirely based on stocking of wild fry with no liming, fertilization, artificial feeding or aeration of the pond which depended on either rain water or tide for water supply. With time, aquaculture knowledge, science and technology (AKST) has gradually developed and has undergone rapid changes. While, low levels of aquaculture were the general practice in the beginning, the trend has been towards intensification in pond culture driven by an increasing demand for fish and the decreasing land area suitable for expansion. Intensification entails the use of any combination or all of the following:

- Development of artificial spawning techniques making it possible to produce fry of desired species on a commercial scale
- Development of superior brood-stocks by selective breeding to produce superior genetic quality fry
- Liming and fertilization of the pond to induce the growth of natural food organisms
- Formulate and use of balanced artificial feed to promote good growth to the farmed species
- Use of pumps to ensure and stabilize appropriate water supply in the farm
- Use of artificial aeration to ensure oxygen supply at all layers of the farm water thereby increasing farm carrying capacity
- Use of pesticides to control predatory or harmful organisms
- Use of probiotics to maintain quality of pond environment
- Use of genetically improved brood stocks
- Post-harvest care ensuring freshness of the produce and good market price

At the present time, aquaculture in Asia is characterized by its wide diversity in terms of species and culture systems. It includes freshwater, brackish water, and marine ecosystems. The species used for aquaculture production include a large variety of fin fish, shrimp, crab, oyster, mussels, abalone, sea cucumber and even seaweed. Aquaculture is practiced in various systems: earthen ponds, tidal flats and paddy fields with peripheral dykes, concrete tanks, raceways, pens, cages, stakes, vertical or horizontal lines, afloat or bottom set, racks, etc. Monoculture, polyculture, integrated aqua-agriculture, etc have developed to suit the region's diversified aquatic environment.

Species-wise or ecosystem-wise breakdown of ESAP aquaculture products by volume and value in respect of 2004 are given in Table 10 and Figures 11-12 (FAO, 2007b). As indicated in Table-10, finfish of freshwater, marine and diadromous species constituted 46%, aquatic weeds 25%, mollusks 22%, crustaceans 6% and miscellaneous aquatic animals and their products less than 1% of the total production (Table 2.14). Their percent contributions by value were 49, 12, 14, 23 and 2% respectively. You are repeating the table here why not say the major categories and say that the fish generally account for about 70% of the economic value?

[Insert Table 2.15: Aquaculture production by species groups- 2004]
[Insert Figure 2.17: Percent contributions in aquaculture by volumes of different species groups]
[Insert Figure 2.18: Percent contributions in aquaculture by value of different species groups]

Of the total production of 24,526,070 MT of fin fish in 2004, carp alone accounted for 15,675,739 MT or 64%. By value, carp contributed 48% of the value.

Range of culture species. As of 1950, only 56 species were reported in Asia. By 2003 this increased threefold to 177 (Table 2.15). Several species are not accounted for in the reporting of production and value mainly because their volumes are very small and therefore do not figure in the official statistics of the countries.

[Insert Table 2.16: Number of species farmed in Asia by FAOSTAT grouping]

2.3 AKST Systems: Actors and Institutions

2.3.1 Milestones in AKST

The application of science and technology to crop production was set to proceed rapidly in the 20th century, especially after WW II. Key scientific discoveries and technological developments in the previous hundred years were supporting the beginnings of major changes in agricultural practices that had been suspended by two successive world wars. For centuries since the origins of agriculture in the Neolithic Age, agricultural technologies had developed slowly, without a firm basis in scientific understanding. Nonetheless, it had, as elsewhere, provided many solutions in ESAP to food and fiber production and the management of natural resources, in this case resulting from the influence and interaction of both European and Asian traditions. Witness the wide range of landraces of the many crop and horticultural species, the cultivar of breeds of domestic and companion animals, and the many production systems, including legume rotations, storage and use of animal manures, tillage techniques, fallowing, irrigation and mechanization with animal, human, and most recently engine power then evident within a region rich in environmental, ethnic, and colonial diversity.

Key scientific findings in the nature and chemistry of life and growth of plants, including essential macro- and micro nutrients, hormones, legume symbiosis, pathways of photosynthesis and respiration, combined with photoperiodism, and genetic recombination to provide both scientific explanation of past successes and the scientific platform for even more rapid development of technologies in the future. Key technologies available at the start of our period of analysis including long-term fertility trials, Haber-Bosch process for recovery of atmospheric nitrogen, breeding strategies, hormone-based chemicals to control weeds (2-4 D), were supported by developments from outside agriculture in better engines, hydraulically operated machinery, the beginnings of insect control (DDT). For historical perspective of these technoligcal developments see Evans (1998).

The return to world peace was itself an impetus for development. World population, around 2.5 billion in 1950, would increase to 6.5 billion, and ESAP population reach 3.4 billion, in the period of this analysis. The debate about whether population increase caused increased food production (Boserup 1965) or the reverse (Malthus 1798/1970) is an interesting but unnecessary concern to this analysis.

Progress in agriculture has been the driving force for the decline in poverty in Asia, from 947 million people in 1990 to 702 million in 2002. Nevertheless, nearly 70% of the world’s poor live in Asia, and more than 500 million of those remain undernourished (FAO, 2004; UNDP, 2005). Technological developments have been applied unevenly throughout the countries of ESAP where many poor farmers still remain relatively untouched by them. For others, though, and for most agricultural production and consumers in the region, the impact on food production and the environment has been enormous. The discussion will return to the plight of poor farmers once the scope of possibilities and impacts of AKST have been explained with reference to three examples, rainfed wheat production in Australia, the intensive irrigated rice system of south and south-east Asia, and the rice-wheat system of the Indo-Gangetic Plains. The objective is to show

how farmers have selected and adapted available technologies to their needs in response to threats and opportunities from changing environmental and economic conditions.

Rainfed wheat production in the State of Victoria, Australia. The Australian wheat industry, as exemplified by this analysis of yield trends in the State of Victoria, had already passed through two phases of technological development before 1950. These and two subsequent phases are depicted in Figure 2.18 (Connor 2004) where mean yields for each year from the outset around 1840 are related to key changes in the application of technology. The lines that depict the time trend are drawn through the high yields and so present a picture of best crop performance in this region where in many years yields are substantially reduced by low rainfall. This should move to the legend of the figure

At the outset (Phase I), when wheat (W) was largely grown continuously (WWW) on parts of farms as suitable land was cleared from native vegetation, yield fell gradually from 1.5 t/ha to around 0.3 t/ha by 1900. Loss of natural fertility, certainly, and build-up of soil borne diseases, probably, contributed to this decline but also important was the gradual expansion of wheat production into areas of lower and less certain rainfall. The solution for those who survived the drought and economic depression at the turn of the century was to adopt new technology. A fallow year (F) was introduced into the cropping sequence (FWFW) to conserve water from one year to the next and, following experiments by Lawes et al in UK, phosphorous fertilizer was applied to wheat (Phase II). Mean yields responded during that phase rising back to the starting values of 1.5 t/ha by 1950, but then achieved on just one half of the total area devoted to wheat production. Other innovations were also important during this period. Most important was the breeding of a succession of disease (rust)-resistant wheat cultivars increasingly better adapted to the short growing season and the harsh environmental conditions. This technological contribution that commenced with germplasm imported from India and Europe and continues to the present day as part of a now coordinated world-wide effort. Farmers also contributed and adapted other technologies with notable examples being the stump-jump plough for tilling incompletely cleared land, the stripper harvester for one-pass wheat harvesting, and steam locomotion to provide greater power than could be provided by horses.

[Insert Figure 2.19: The development of wheat yield in the State of Victoria, Australia, since the inception of the industry.

The rapid development of a lucrative world market for wool in the years following WWII provided an opportunity for a great change (Phase III). It then became economic to improve pasture productivity by attention to species composition and fertility. ‘Sub and super’ (subterranean clover (Trifolium subterraneum L.) and superphosphate fertilizer) became the password for pasture development. Sheep carrying capacity of pasture increased markedly and encouraged close integration with wheat production. Pastures were managed for sheep grazing and to build up N fertility that was then extracted during a subsequent cropping phase. Sequences of different lengths were suited to different soil and environmental conditions (e.g. FWP, PPPFWWW etc). The cycle of legume-based pasture and wheat, known as 'clover ley farming' is justifiably an Australian invention (Smith, 2000). Other technologies supported the greater economic benefits that flowed to farmers from increased productivity of wheat and sheep. Continuing plant breeding, now also of pasture species, has already been mentioned. Horses were replaced by tractors and new machines were developed. Herbicides and pesticides became available and increasingly precise fertilization, including micro-nutrients, especially for pasture legumes (Mo, Mn), became possible. Fallowing became less frequent and the cropping phase more intensive than previously, as it was established that much of its advantage during Phase II was from weed and disease control and management of N fertility by mineralization rather than from moisture conservation. Those contributions to yield could now be obtained by different methods. Wheat yields rose to a new plateau, around 2 t/ha by the 1980s. During that period, ley farming was commonly seen as the ecologically stable system (sustainable and 'green'). With the application of inorganic nutrients, leguminous pastures that supported a profitable sheep enterprise increased N fertility for profitable wheat production. The system did not, however, persist into the 1990s.

The major cause of the decline of 'ley farming' was the collapse of the wool market. Suddenly, sheep were an economic liability and numbers fell nationally from over 200 million in 1990 to 92 million in 1992. Associated causes were unanticipated environmental effects of the system itself. Soils, already acid, acidified further under this extractive system run at high fertility. Clover growth and N fixation was reduced as was in consequence the overall productivity of pastures and crops. Acidification is an onsite problem that can be corrected by liming, a solution known to the Romans, but in this case rarely economic. A further more difficult, off-site problem was dryland salinization. Even in this semi-arid region, more water was able to drain below fallows and annual crops and pastures than under the perennial evergreen eucalypt-dominated vegetation that they had replaced. The resultant rise in water tables brought salt to the surface in the lower parts of the topography, first reducing, and later preventing, crop growth, and also exposing soil to erosion and streams to a high salt load. The solution lays in changing the water balance to keep the salt at depth where it was under the native vegetation. Thus in Phase IV, a more diverse system is now sought that involves less pasture, even less fallow, perennials such as lucerne and trees in agroforestry systems along with a wider range of crops including canola and pulses lupin, field pea, fababean, chickpea, and lentil. There is also increasing use of zero tillage, controlled traffic, yield mapping, and precision farming to maintain or improve soil structure and to deal effectively with natural variation in increasingly larger crop areas. Nitrogen fertilizer has entered the system for the first time while plant breeding continues, now for a wider range of species, and applying new techniques in biotechnology (e.g. marker assisted breeding) but so far avoiding genetically modified crops. While there is some local opposition to the use of GMOs, the dominant concern is for continuing access to the overseas markets to which most crop production is destined.

Farmers in the current Phase IV require technological and economic skills to manage increasingly complex cropping systems. High yields are possible only in the years of greater than average rainfall. In low rainfall years, the focus of management must be to minimize costs, perhaps even not to crop at all. The importance of this variability is seen dramatically in the small yield (0.25 t/ha) obtained in the drought year of 1982 that was followed when the drought broke in 1983 with an almost record yield of 2.5 t/ha. It is now accepted that such drought-and-release sequences can be predicted with reasonable skill by the El Niño Southern Oscillation (ENSO) Phenomenon and such predictions are now used to assist farmers apply tactical variations to their cropping strategies. Cropping is now not a matter of applying established cropping sequences but rather adjusting crop type and management to likely seasonal and economic conditions. Nitrogen fertilization is a good case in point. The objective is to gain yield benefit in years of high potential and avoid the possibility of yield loss due to haying off (Van Herwaarden et al. 1998) in years of low rainfall. This requires not only an interest in weather data but also, for application to individual crops, measurements of soil water and nitrogen content at sowing and later of crop nitrogen content at responsive points during the growing season. Measurements and their analysis are the keys to success in crop choice, crop condition, weed and pest incidence and the likely success of management interventions. Crop simulations models and computer based decision support systems are finding a role in the application of technology to the management of commercial farms.

Farmers do not work alone. They contribute financially, but also actively, to guide research to improve sustainability of cropping systems through the Rural Industries Research and Development Funds. In this way, they benefit from public and private research activities and also from public and commercial advisors who maintain awareness with new developments that often either originate with or have been modified by practicing farmers themselves.

Irrigated rice production – the Green Revolution

Irrigated rice production (paddy rice) had developed over centuries as the iconic production system of Asia providing the staple food of millions. It relied on the ability of rice to withstand waterlogging and in that way to compete with most potential weed species. It developed in places that were seasonally flooded and benefited from the introduction of nutrients in silt. The aerobic-anaerobic transitions were also able to mobilize nutrients. Irrigation drawing on ground water extended its distribution. Cultivars had been developed for many environments and for crops grown at different times of the year. Double cropping of rice became common in China about 1,000 years ago and triple cropping probably started in the 14th century. Around 1,000 years ago, rice yields in China and Japan were about 1 t/ha and it took several hundred years to increase them to 2-3 t/ha in the 1950s (Greenland, 1997).

The single most important innovation that has led to great increases in rice yield was, as previously with wheat, the incorporation of dwarfing genes. When the International Rice Research Institute (IRRI) was formed in 1960, scientists there soon discovered that the main constraint to rice yield was the architecture of the traditional tropical rice cultivars (Khush et al., 2001). Although tall cereals were advantageous because they competed well with weeds and provided substantial amounts of straw for fodder, fuel and construction as well as grain, they lodged under the conditions of high fertility required to produce high yields, to the detriment of both straw and grain. Tall cultivars responded positively to fertilizer-N, but only when they were supported by bamboo sticks. The Japanese had realized the value of short-straw cultivars to the quest for high yield and had begun introducing such traits into rices at the turn of the century. By the 1950s, dwarfed rices could be found among the multitude of land races in many Asian countries, but also some semi-dwarf rice cultivars in the subtropical area of China in the 1950s. Taichung Native 1 (TN1), a semi-dwarf cultivar from Taiwan, was first planted in the tropics in the late 1950s, but it was highly susceptible to major diseases and insects in the tropics (Peng and Khush, 2003). In 1962, IRRI introduced dwarfness into tropical rice by crossing the dwarf Taiwanese cultivar Dee-geo-woo-gen into the tall Indonesian cultivar Peta. The result, officially named on November 14, 1966, was IR8 (the 8th cross), the first lodging resistant and hence fertilizer responsive cultivar, that was rapidly adopted by farmers to become the symbol of the 'Green Revolution' in Asia. After the release of IR8, three more semi-dwarf cultivars, IR5, IR20 and IR22, were released during the 1960s, followed by another 17 in the 1970s and 13 during the 1980s (Peng and Khush, 2003). The birth of IR8 increased the yield potential of tropical rice from 6 to 10 t/ha. Its yield potential has hardly been surpassed in 40 further years of breeding (Peng et al., 1999).

The release and widespread adoption of short-duration, high-yielding, semidwarf cultivars triggered investments in irrigation infrastructure and allowed farmers to grow two to three rice crops per year (Figure 2.19). Tillage and management intensity increased and soils remained submerged for longer periods. The use of external inputs increased and the diversity of rice cultivars used in the irrigated systems decreased. Higher yields resulted from the combination of increased yield potential of modern cultivars compared to the land races they replaced, improved crop nutrition made possible by fertilizer application, and improved host-plant resistance and pest management to minimize losses from weeds, insects and diseases (Cassman and Pingali, 1995b). World average rice yield increased from less than 2 t/ha in 1960 to 4 t/ha at present (Figure 2.19). In the irrigated lowlands of Asia, which account for 75% of the world's rice production, average yield increased from 2-3 t/ha in the 1950s to 5.3 t/ha today. Good rice farmers in the humid tropics typically harvest 6–8 t/ha in the dry season and 5–6 t/ha in the wet season, enabling production of staple food in Asia to stay ahead of population growth and reduce the number of underfed people (Dobermann and Cassman, 2004).

[**Insert Figure 2.20**: Trend in average world rice yield (1960 to 2005) and the key technological interventions associated with it. Changes in breeding objectives and release years of selected key rice cultivars are indicated in the bottom half. Major changes in crop management triggered by the availability of short-duration, semi-dwarf, high-yielding rice cultivars are indicated above the yield trendline]

Rice breeding provided the fundamental basis for the remarkable intensification of rice production in Asia. Breeding objectives at IRRI and national rice research centers in Asia have changed during the last five decades (Peng and Khush, 2003; IRRI, 2006):

- 1st decade (1960-1969): dwarfism
- 2nd decade (1970-1979): multiple disease and insect resistance
- 3rd decade (1980-1989): grain quality
- 4th decade (1990-1999): high yield (hybrids, new plant type), abiotic and biotic stress tolerance
- 5th decade (since 2000): precision breeding taking advantage of the rice genome information: adaptation to abiotic (nutrients, drought, submergence, salinity, high temperature) and biotic stresses, improved grain quality and nutritional value (Zn, Fe, Vitamin A).

Although the quest to increase the yield potential of inbred rice after the release of IR8 has not been successful yet, many new rices have been produced that are better adapted to different environments and also contribute to better nutritional quality and human health (Peng et al., 1999; Peng and Khush, 2003). Considerable progress has been made, for example, in managing major rice diseases such as bacterial blight, blast and tungro through genetic improvement. That few disease outbreaks have occurred in the past 15 years is the result of collaborative research starting from basic investigation of host-plant interactions to the deployment of effective genes in farmers' fields. Likewise, combining resistance to insect pests with ecologically based crop management principles (Heong et al., 1995) has greatly reduced the incidence and impact of pest outbreaks (IRRI, 2006). The Green Revolution has not only increased rice yields, it has also decreased yield instability (Janaiah et al., 2006), which has often been the cause of famines in the past.

The experience of the rice breeding programs at IRRI and its partners in numerous countries of Asia demonstrates how productive agriculture requires continuous release of new cultivars as a driving force for securing the world's food supply. Currently, modern rice cultivars (MC) that have their origins in breeding research done during the 1960s cover 75% of Asian rice land. In irrigated areas, that proportion is often in the 80-100% range. In Bangladesh, for example, 46 MC have been released from 1970 to 2001, and they had spread to 80% of the dry season irrigated rice area by the early 21st century (Table 2.16). The adoption of these modern cultivars has contributed to a growth in rice yield at 2.3% per year over the last three decades, which has for example helped Bangladesh to avoid a looming hunger crisis despite high growth of population and decline in arable land (Hossain et al., 2006).

[Insert Table 2.17: Technological progress in rice cultivation in Bangladesh. Adopted from Hossain et al. (2006)]

Yields and production of irrigated rice in Asian rice farms continue to grow, but at a slower pace. From 1967 to 1984, rice production in Asia grew at an annual rate of 3.2%, mainly because of yield increases (2.5% /y). However, growth rates declined to 1.5% /y (production) and 1.2% /y (yield) during the period 1984-96. This slowdown was partly due to lower rice prices and the slowdown in demand growth due to secular trends in population and per capita consumption of rice, but concern was also raised about a possible resource degradation (Cassman and Pingali, 1995a). Yield declines were observed in some long-term research experiments, but are not widespread at current production levels (Dawe et al., 2000). However, in some large rice production domains where farmers were early adopters of modern irrigated rice production technologies, yields have stagnated in recent years (Cassman and Dobermann, 2001).

The Green Revolution in ESAP has received much criticism from sociologists and environmentalists, but much of it is unwarranted. Lowering water tables, salinization, soil nutrient mining, and negative effects of agrochemicals (fertilizers and pesticides) on the environment and human health have all been observed in some places (Pingali and Roger, 1995; Ali et al., 1997; Dobermann et al., 1998; Bouman et al., 2007). They are not necessarily a failure of the Green Revolution technologies required for rising yield or because many poor framers do not have access to the necessary inputs to achieve high yields. In many cases, they result from misuse or insufficient knowledge. Irrigated rice systems are in fact among the world's most enduring, environmentally sound, and productive agroecosystems. Rice is the only major food crop that can be grown continuously, without the need for rotation, producing up to three harvests a year. In many respects, irrigated rice systems pose fewer threats to the environment or sustainability than most upland production systems. They provide a rich array of provisioning, regulating, and cultural ecosystem services (Bouman et al., 2007). Water retained in bunds increases groundwater recharge. Rice can be grown as a desalinization crop. Soil degradation and erosion are negligible. Acidification is less of a problem because the physical chemistry of flooded soil systems causes soil pH to stabilize around 6.5 to 7 after flooding. Irrigated areas contribute to cooling of air temperature in peri urban areas. Risks of water pollution caused by inorganic fertilizer are minimized by the particular conditions in the floodwater-soil system. Atmospheric CO2 and N2 fixation by aquatic flora and fauna contributes to maintaining yields and increases soil organic matter (Roger, 1996). Fish and ducks are raised in rice fields, ponds or irrigation canals. Irrigated rice landscapes generally sustain rich biodiversity. Those unique features are the primary reason for the unparalleled sustainability of lowland rice monoculture in Asia, supporting civilizations for thousands of years by providing a stable food basis and a wide range of nonmaterial benefits, including aesthetic, spiritual, religious, educational, cultural and recreational values associated with rice cultivation (Greenland, 1997).

Realism is required regarding the potential productivity of crops and the technological requirements needed to achieve them. Average yields of irrigated rice must reach levels of 6.5 to 7 t/ha until 2020 (Dobermann and Cassman, 2004). Economic development will continue to increase personal income. Although diets will change dramatically as incomes rise, rice demand will increase at an annual rate of about 1%. There will be little, if any, net increase in rice cropping area or in the amount of irrigated land available for rice production. Labor costs will continue to rise, favoring the adoption of mechanized technologies. Land preparation, crop establishment, and harvest are labor-intensive farm operations in transplanted rice and farmers will increasingly seek ways to reduce costs associated with them. Competition for water resources will intensify. Where feasible, cropping systems will diversify, but rice monoculture in double- or triple-crop systems will remain the preferred choice in many lowlands with heavy soils and other constraints to growing upland crops.

Research now addresses technological solutions to these new challenges (Figure 2.19), including breeding to reduce the need for pesticides, irrigation methods to increase efficiency of water use and reduce offsite effects (Bouman et al., 2007), and management strategies so that the key nutrient N can be utilized more efficiently and mining of other soil nutrients is avoided

(Dobermann et al., 2002; Peng et al., 2006; Pampolino et al., 2007). New molecular tools and the availability of the rice genome have allowed directing breeding towards more specific targets such as improving submergence tolerance into rice cultivars (Xu et al., 2006), enriching rice grain with more vitamin A and micronutrients (Potrykus, 2001; Lucca et al., 2001), and improving the tolerance to heat stress may result from the global temperature increase (Matsui et al., 2005; Prasad et al., 2006). Biotechnology promises the potential of further major advances, for example the transfer of C4 photosynthesis to rice to improve both productivity and resistance to high temperature (Sheehy et al., 2000). These advances will satisfy socioeconomic and biophysical needs for rising yields and they will also make major contributions to the wide range of ecological services that are associated with irrigated rice.

The rice-wheat system of the Indo-Gangetic plains. Rice-wheat (RW) cropping systems have been practiced for 1000 y (Tran and Marathee, 1994) but have only expanded rapidly, and that especially in NW India and in Pakistan, since the mid-1960s, following the introduction of the Green Revolution (GR). The systems now occupy 13.5 Mha in the Indo-Gangetic Plain (IGP) of South Asia (Timsina and Connor 2001). R-W systems have evolved differently depending upon location with the introduction of wheat into traditional rice-cropping areas as in Bangladesh, eastern India and Nepal and rice into traditional wheat growing areas of north-west India. The driving force for expansion has been the need to intensify cropping to meet the increasing demand for food and was made possible by the development of short- and medium duration cultivars of both rice and wheat. Productivity has, however, also responded to improved nutrient management, pest control, and the expansion and improvement of irrigation.

[Insert Figure 2.21: Progress of yield improvement (1950 to 2005) in rice-wheat systems of Indo-Gangetic Plains and the sequence of contributing factors]

A summary of the sequence of the application of technology and its impact on productivity and the environment in the IGP is presented in Table 2.16 (J Timsina, pers comm.) and on yield performance in India in Figure 2.20 (JK Ladha, pers comm.). Table 2.17 identifies five phases of development starting from before the Green Revolution and distinguishes between actions and responses in eastern and western regions. Figure 2.20 records the continuing increase in average yield in India from 1950 to the present resulting from the continuing application of new cultivars and management techniques. The rice-wheat system is complex with the need to establish an overall optimum management strategies for the alternating and contrasting anaerobic and aerobic environments required for rice and wheat crops, respectively.

The development sequence of technologies reveals the sequential attention that has been paid to limiting factors. Initially, in Phase I, prior to the Green Revolution (GR), yield was small and the system operated with low inputs and much human and animal labor. Then, during GR (Phase II), short-season cultivars of rice and wheat became available and improved management focussed on that combination together with expanded irrigation and improved management. During this phase, development in the Eastern IGP fell behind the Western IGP. As in the previous phase of early expansion there were no environmental issues to counteract the benefits from increasing productivity. Yield increase continued with further intensification in Phase III. Although once again, development was slower in the eastern section. The components of intensification were now in cultivars, nutrition and mechanization. Early sowing of wheat was identified as a major strategy for yield improvement to avoid heat stress and low yield during flowering and grain filing. In Bangladesh, for example, studies established a yield loss of 44 kg/ha/day for crops sown after the optimum date of 1 Dec (Ahmed and Meisner, 1996). During the subsequent Phase IV, yield increase slowed as yield declined in some places due to a cultivar of causes. There is general evidence of deterioration of soil structure and fertility due to excessive cultivation and excessive nutrient extraction from the more intensive system operating at ever increasing yields (Figure 3). Problems also arose from irrigation practice with both excessive extraction of ground water and accumulation of salts in regions of low water quality. Ladha et al. (2003) summarized the data from various studies and concluded that delay in planting (mainly for wheat) and decline in soil C and soil N, P, K, S, Zn, B, Cu, Fe, and Mn were mainly responsible for yield stagnation or decline in rice and wheat yield during this period. There is also evidence that decreased solar radiation and increased minimum temperature also contributed to yield decline (Pathak et al 2003).

The current Phase V is one of recuperation of yield and attention to input use especially water and labor and also environmental problems so that many new technologies are being applied across the entire IGP. New techniques and machines for planting enable more rapid and timely crop establishment. Reduced cultivation and site-specific fertilizer management are reversing the soil deterioration of the previous phase. Bed planting is introduced in some places to improve water management and crop diversification in rice-wheat system. Fertilizer requirements are more precisely defined and techniques of soil and tissue testing enable more effective and efficient nutrient management. Laser levelling of land aided by more accurate definition of water requirements is improving irrigation efficiency. Reduced stubble burning is contributing to improved air quality as well as to greater soil organic matter. These “resource-conserving technologies” are aimed at improving farmers income through increasing input use efficiency, maintaining crop productivity and enhancing crop diversification (see Gupta et al 2002 and Ladha et al 2003).

Organic agriculture. Concerns about the environmental and food safety aspects of the use of agrochemicals in agriculture, especially pesticides, quickly led groups of European farmers to discard the integrated approach to agriculture (traditional methods plus agrochemicals), as exemplified in the three major production systems discussed in the previous subchapters, and to form the organic movement, relying upon traditional methods of soil, nutrient and weed management (refs needed?). These methods, that were highly developed in medieval Europe, and with origins readily traced to the writings of the Roman Columella, are designed to make the best use of natural cycles of nutrient flow, pest and disease control, and competition to control weeds. To these, modern organic farmers add new technologies provided they are not based on synthetic fertilizers or chemicals, and more recently, genetically modified organisms. The organic movement has spread world wide and now includes various sub groups (e.g. biological agriculture, ecological agriculture, nature farming, permaculture, biodynamics etc) that farm within guidelines of organic production (EU 2000, FAO/WHO 1999, IFOAM 1996). Organic agriculture provides one set of solutions to deleterious effects of agriculture on food quality and the environment insofar as they are related to immediate and residual effects caused by the overuse or misuse of agrochemicals.

Organic agriculture has two faces in ESAP. First there is a small sector of farming that produces certified organic produce for the home market and also for export to developed countries. Bangladesh has the largest proportion of land (1.9%) devoted to organic agriculture, with Sri Lanka (0.65%), China 0.6%), and Japan (0.56%) also relatively large contributors (Willer and Yussefi 2006). All other countries fall below 0.2%, and most below 0.1%. This analysis omits Australia because the available data are confused. Australia has by far the largest area of certified organic agriculture in the world (13 Mha, 40% of the worldwide area) but it is not a country with large organic production of crops (fruits, vegetables and cereals). The reported area includes 11 to 12 Mha of extensive zero-input grazing lands of low productivity, few products of which enter the certified market. In developed countries, organic production is supported by a price premium and a significant proportion, up to 10% of fresh fruit and vegetable sales, in some developed countries (e.g. Denmark) but premiums and market share are both less in the developing countries of ESAP (* any data on market share). Second, there is a much larger proportion, mostly of subsistence farmers, who farm organically because they cannot purchase, or cannot afford, the synthetic inputs. The question arises as to what trends are evident in the development of organic relative to integrated agriculture in ESAP. The following describes the forces that are shaping this development.

In the first place it is important to recognize how concerns over food and environmental safety, to a large extent highlighted by the organic movement, are impacting on integrated agriculture and changing the choices available to consumers. This is occurring strongly in developed countries where markets for agricultural products from ESAP can be found, but also in the ESAP region itself (e.g. China, Thailand, Malaysia). Organic agriculture led the way with certification of production methods but there are now labels that compete with organics on the basis of both food and environmental safety (e.g. AFFA 2001, EISA 2001, EUREPGAP 2001a&b). Their characteristic is that food is produced according to protocols of Good Agricultural Practice (GAP), i.e. by methods that combine the benefits of biological cycles with the proper and safe use of agrochemicals, as well as meeting other social and environmental goals. These alternative certification schemes control market access in many local stores and, importantly, are required for export of commodities from ESAP to developed countries. The additional driving force for these developments, over and above the demand by customers for safe and environmentally friendly production, has been the legal determination in developed countries that retailers are not merely intermediaries between producers and consumers but are responsible for the quality and safety of the goods they sell. Discriminating consumers can now select between organic produce, concluded to be safe because of the production method, and products with a range of other labels that are subject to chemical analyses as well as protocols for production, storage, and distribution. The impact of these options can be seen in the shelf space devoted to competing products in supermarkets of developed countries, reports that organic production now exceeds sales (e.g. Denmark), and in the spread in ESAP of EUREPGAP certification of producers seeking to export products to EU countries.

Second, applicable technologies cannot greatly increase the productivity of organic agriculture because it is constrained by nutrient supply. Agriculture, of any type, is an extractive activity that cannot retain high fertility and productivity without replacement of nutrients exported with the products or lost from the site during production. Although high yielding crops can be produced organically, this is only achieved, once natural fertility has been exploited, by refuging nutrients from other areas, as plant remains or animal faeces, or by accumulating them, in situ, in long fallows (slash and burn farming). The consequence of this, not evident to most consumers, and overlooked by many proponents, is that a much greater land area than is immediately apparent is involved in any unit of successful organic production. In contrast, crops can be grown more frequently, and often repeatedly, with fertilizers on the same land, e.g. the examples of the intensive rice and rice-wheat systems described above. Furthermore, in integrated agriculture, the nutrient requirements of crops for high productivity can be met more precisely and efficiently, in constituent elements or amounts, than with organic manures of variable composition. The total productivity of organic agriculture (not that of some individual crops) is thus much less than for integrated agriculture.

It is the shortage of land that will restrict the contribution that organic agriculture can make to world food supply. The large world population, presently 6.5 billion, and likely to exceed 9 billion by 2050, will increasingly demand high agricultural productivity so that human demands can be met and as much land as possible can be spared for nature and its other environmental and cultural services (Waggoner 1994, Balmford 2004). Organic agriculture was the norm at the beginning of the 20th century when the world population was 1.5 billion. Now, there is not enough land or organic matter to support the crop production needed for the present, let alone the anticipated world population. Studies by Burringh (1977) and Buringh and van Heemst (1979) established that best practice organic agriculture was unable to feed the world population, then around 4 billion. Organic agriculture cannot be the solution to food production for a heavily populated planet. Attempts to do so would reduce the efficiency of use of land allocated to agriculture and would 'sustain poverty and malnutrition' in underdeveloped countries. Pretty et al (2006) provide a recent analysis of the impact of 'resource-conserving' technologies on agricultural productivity that includes organic agriculture. The study concludes that poor households benefit from greater yields by adoption of improved practices, and that yield gains from a low base are usually the greatest but cautions that productivity of these system is probably insufficient to meet future food demand. Given the limitations of nutrient supply, none of that surprises, but worryingly the paper omits details needed to define the actual comparisons and provides no values of crop yield.

Biofuels. The low productivity of organic agriculture is further threatened by the current promotion of biofuels because their large scale production will apply enormous pressure to all agricultural production systems and to the natural environment. At a time when concern is expressed at the capacity of agriculture to feed an anticipated world population of 9.5 billion, the scale of this additional pressure can be gauged by the amount of grain required to fuel a motor car with bioethanol for one year. That amount of 3.5 t is almost seven times the annual grain equivalent of agricultural production required to provide each person with an adequate and balanced diet (Connor and Minguez 2006). Put another way, the ethanol to fill the tank of a car just once (40 litres), that could be produced from 100 kg grain, has the calorific content (100 x 4000 kcal) equal to the survival diet (2200 kcal/day) for one person for just 6 months. Two fill-ups, and around 1000 km of motoring in the developed world, for a whole year's survival ration in the developing world! These simple calculations expose the enormous increase in agricultural production that would be required for any significant contribution by biofuel to private motoring alone, and the inequality it could engender in developing countries struggling to feed all inhabitants adequately (von Braun and Pachauri 2006). While farmers will benefit from the additional market for their produce, the reality is that even a small proportion of total liquid fuel requirement produced from agriculture will place enormous strain on the environment. The notion that are there are special fuel crops that are significantly more efficient fixers of solar energy than current crop species, or will flourish on land that is currently unsuited to agriculture, is misguided. When, methods are devised to break down the cellulose for fermentation, stubbles and biomass crops can be a source of biofuel also. Stubbles, however, play an important role in maintaining soil structure and fertility and while a proportion, perhaps 50%, might be removed from the highest yielding crops, retention is generally required to sustain productivity. Witness the deleterious impact of the removal of stubbles cattle fodder and roofing and root crowns for fuel that is now practiced in some parts of the rice –wheat system described previously. Energy crops will indeed compete with food crops for land and markets and, to the small extent that they will be able to contribute, will require high levels of management and, most importantly, large inputs of water and nutrients to maintain the required productivity.

The resource-poor farmers of ESAP must be drawn into systems of high productivity for their own food supply and wellbeing. The path is long, but these activities are essential because greater overall production cannot be achieved with low input methods. Practical education in the safe use, storage and disposal of agrochemicals is needed, as are regulations at National levels to ensure compliance. Only a small proportion of producers will benefit from organic production for domestic or export markets. The principles of organic agriculture will, however, remain an important contributor to safe and environmentally friendly food production because they remain firmly embedded in integrated agriculture from its evolution during the past half century from medieval (organic) agriculture. This is evident in all modern systems of integrated agriculture and was well exemplified by the central role of legume rotations in the analysis given in an earlier section of the wheat-sheep system of the Australian wheat belt. This seems to be out of place. It is at the end of biofuels but is really something that is important for the point on green revolution and any intensive agriculture.

This text that was probably taken from chapter 5 needs to be integrated into here

Organic agricultural systems. Organic agriculture systems were developed initially in Europe, New Zealand and Japan (ESCAP, 2002), although the impetuous for this development came, in part, from European exposure to traditional agricultural processes in India (IFAD, 2002). They fall somewhere between traditional and conventional agricultural systems, sometimes coming close to the former, and sometimes to the latter, varying from augmented traditional systems to modern monocultures. They tend to resemble traditional systems in that they are based on complex integrated systems that maximise biodiversity, minimise off-farm inputs, and produce a range of outputs. They have evolved often from traditional practices and farmer trial-and-error. Until recently there has been little formal institutional research. However the rising popularity of organic products, and often-higher financial returns for farmers, is driving a conversion of conventional farms to organics, and increased institutional research. Organics is increasingly blending appropriate modern agricultural techniques with traditional methods, and it offers a promising option for the future that can provide increased productivity, and decreased environmental and health effects caused by the chemicals used in conventional systems (ESCAP, 2002).

The area under organic cultivation in Asia and the Pacific is small, and lags behind other areas such as Latin America, in part because development and uptake by farmers has been hampered by a lack of supportive government policy in many countries (ESCAP, 2002). However it has the potential to provide a major contribution to meeting the goals of sustainability and development in the Asia and Pacific region (ESCAP, 2002). Organic agriculture is particularly suited to increasing productivity of marginal lands, and especially for the rural poor with few resources to spend on chemical inputs. Additionally the higher diversity of crops and animal agriculture on organic farms leads to an improved distribution of food and income throughout the year (ESCAP, 2002).

Organics, through its emphasis on building soil structure, fertility and health by the incorporation of organic matter, has a significant role to play in the rehabilitation of degraded agricultural lands where erosion, compaction, salination and desertification have significantly reduced yields and threaten any future agricultural use (FAO, 2002). The incorporation of organic matter into the soil also improves water-holding capacity, which is essential in areas of poor/erratic rainfall and potentially higher evapotranspiration which may result from global warming (World Bank 1992, as cited in IFAD, 2002a; FAO, 2002). Additionally, organic systems appear to be more stable and resilient in response to climatic disruptions (FAO, 2002). Conventional rice production in Japan was nearly wiped out by a cold summer in 1993, but organic systems yielded 60-80% of the annual average. This better performance was believed to be a result of better composition of water-stable aggregates in organic soils and reduced soil compaction (FAO, 2002).

Organic agriculture's emphasis on the sustainable use of local, often free, resources also makes this system of agriculture particular important for the rural poor in Asia, and especially women-headed households because of women's greater difficulty in accessing financial resources to purchase seeds, fertilisers and pesticides. It also removes the exposure to pesticides, which have had a significant impact on the health status of the rural poor (Rengam, in press; ESCAP, 2002).

The ESCAP (2002) report, Organic Agriculture in Asia and Rural Poverty Alleviation, found a positive interrelationship between organic farming and improvements in rural livelihoods, including positive effects on employment, income, and household food security. For example, there has been an observed improvement in the health status of members of the Nayakrishi

Andalon organic movement in Bangladesh, which includes more than 65,000 families (ESCAP, 2002).

The question of yields from organic systems versus conventional systems remains controversial, and the tendency to assume that organic systems automatically have lower yields, because they do not use synthetic pesticides and fertilisers or genetically engineered seeds, has resulted in an unwarranted bias against organics as a means of increasing food production and food security, and meeting the goals of development and sustainability. The evidence shows that some organic crops in some situations offer similar or improved yields to conventional agriculture—such as jasmine rice and baby corn in Thailand (ESCAP, 2002)—and in others the yield is reduced to a greater or lesser extent. In some systems the yield of a single crop may be reduced but the total biomass productivity of the land under cultivation increased, with the additional benefits of providing food to the farmer, which is not always the case with increased yields in cash cropping systems (Pretty and Hine, 2001).

In both Australia and New Zealand, organic agriculture is developing into a lucrative export market driven sector—as well as a thriving domestic market sector, with produce increasingly being sold at local farmers markets. There is also growing demand for organic food in urban centres in many Asian countries, and the premiums paid for this food offer an opportunity for increased incomes for the rural poor, especially in areas largely untouched by the Green Revolution technologies (IFAD, 2002). However there are limitations imposed by the costs of the organic certification demanded by markets.

Organic agriculture has the potential to considerably increase productivity, especially in areas of low-medium productive potential, and on degraded agricultural soils. It can also play an important role in improving the household food security for the rural poor.

Organic agriculture has the potential for considerable social benefits as well as purely productive benefits. Standards for certification of organic agriculture address issues of social justice and social rights, as well as aspects of production, and in this respect may be considered likely to improve the lot of women in agriculture in Asia where organics is taken up. As organic agriculture does not require the purchase of expensive inputs it becomes more accessible to poor rural women who are unable to obtain credit. On the other hand as organic systems need to be developed over a number of years to reach maximum productive capacity women's often insecure access to long-term control over land may be a hindrance (FAO, 2002).

There may be employment effects too: whilst some organic systems may require more labour, and this can be a negative or positive, the crop diversification that generally happens on organic farms does distribute labour requirements through the season. This can contribute to stabilising employment, reducing turnover and alleviating many problems relating to seasonal migration (FAO, 2002).

There are also added environmental benefits in that contamination of ground and surface waters by synthetic fertilizers (especially nitrate leaching) and pesticides are avoided, and sedimentation of waterways from erosion reduced (FAO, 2002). As peak oil approaches, it is important to be cognisant of the use of fossil fuels in agriculture—as fertilisers, pesticides and fuels used to power machinery. Organic agriculture reduces the use of fossil fuels in terms of inputs, although it may use more fuels for cultivation. However calculations on comparative energy use in OECD countries indicate that energy consumption on organic farms is 64% that of conventional farms (Haas & Kolke, 1994a and Lampkin, 1997 as cited in FAO, 2002), whilst other research in Iran and Switzerland puts this figure as low as 30-50% (Zarea et al., 2000 and Fliessbach et al., 2002 as cited in FAO, 2002). In the three year comparative study on organic and conventional strawberry production in China, 98% of the energy inputs in the organic systems were from renewable sources (such as animal manure and biogas), whereas 70% of the energy inputs into the conventional system were non-renewable such as electricity, and chemical fertilisers and pesticides (Xi et al., 1997 as cited in FAO, 2002). In New Zealand, Nguyen and Haynes (1995) found that the mean annual energy input was considerably lower under organic management systems than under conventional management (as cited in Fairweather and Campbell, 2001).

Organic agriculture may also make a positive contribution to dealing with the issue of climate change: "Organic agriculture may not only enable ecosystems to better adjust to the effects of climate change but also offer a major potential to reduce emissions of agricultural greenhouse gases. Moreover, mixed farming and the diversity of organic crop rotations are protecting the fragile soil surface and may even counteract climate change by restoring the organic matter content. The carbon sink idea of the Kyoto Protocol may therefore partly be accomplished efficiently by organic agriculture" (FAO, 2002, p. 53).

In the past, and currently, organic agricultural science research and technological development has been significantly under-funded. This is in part because of the aforementioned assumption that organics produces lower yields, and in part because as organics does not rely on the use of expensive inputs, the impetus for private sector research has been absent. It is posited that, if the same level of funding that has been available for conventional agricultural and now genetic engineering where made available to support the development of organic agriculture, then agricultural production could be increased substantially, whilst at the same time reversing the now widely acknowledged degradation caused by the Green Revolution technologies (ESCAP, 2002), and improving the social conditions of the rural poor of Asia, thus going a long way to meeting development and sustainability goals.

2.3.2 Actors and institutions that have shaped AKST in the region

In the current era which for many developing states may be described as pos-statist, there has been de facto reconsideration of the role of the state. Most governments of such states and development partners, in particular, accept that one of the major roles of the state in the economic sphere is to create and maintain an enabling environment for economic actors to pursue agreed societal goals such as economic development and growth. This subchapter looks at institutional arrangements for research and development, training and extension (RDTE) that will better position AKST systems to address the development and sustainability goal

Institutions and organizations. It is quite common to see the terms “institution” and “organization” used interchangeably in the literature, though these terms have been clearly defined by institutional economists and by the sociology of science community. The institutional economists usually adopt the sociological meaning of the term, referring to things that pattern behaviour- routines, norms, shared expectations and morals (Edquist and Johnson, 1997). The sociology of science community also adheres to this strict distinction between institutions and organizations, the latter being viewed as players or actors whose interaction is governed by institutions (rules, norms etc) (Raina, 2003). The convention in the science and technology policy literature is to use the term institution as an embedded concept although there is much inconsistency. This embedded definition refers to the behavior of physical organizations dealing with research and development (R and D) and economic activity-research centers, universities, private companies, research foundations, farmer associations, co-operatives and so forth (Hall et al, 2003).

Institutions are therefore the rules, norms and conventions that govern interactions among the different actors. In practice this means the rules, norms, habits and practices governing: NOTE this is how the ag assessment is using this term in all the global chapters and the regional reports

a. how research priorities emerge, are promoted and executed
b. the role of various actors involved in production, transfer and use of knowledge
c. the relationships between these different actors and the factors that affect their relationships

d. how performance is evaluated and rewarded (incentives) and by whom
e. how R and D is held accountable to different interest groups and society as a whole
f. how knowledge is built up, shared and used
g. how organizations reflect and learn (Hall et al, 2003).

Exploring institutions is important, as quite often, these “institutions” determine the way the different actors involved in research, development, testing and dissemination of technologies interact with each other and respond to new challenges and opportunities. This is all the more important as the nature of farming in this region (and elsewhere too) is changing rapidly. Plateauing grain yields, declining water and land availability, new threats and opportunities emerging from WTO, emergence of supermarkets, increasing private sector participation, emerging concerns on food safety, need for standards in production and processing have all made production, marketing and trade of agricultural produce more complex (see chapter 3). Addressing these issues needs new ways of working and the involvement and collaboration among a large number of actors/organization. Development of appropriate “institutions” therefore assumes more importance as these would facilitate or constrain the ability of various actors to respond better to these new challenges and opportunities.

Agricultural development is dependent upon the performance of a large number of actors/ organizations. It include not only those involved in research, development, training and extension, but also involved in the generation and distribution of inputs, supply of credit, value addition and marketing, development and implementation of policies and the overall institutional context that shapes the interaction among these different actors/organizations. Table 5.3?? illustrates the type of activities and the broad range of organizations.

Though many of these actors are present in all the countries across the region, there is a wide diversity in the number, capability and performance of these actors. This diversity stems from the historical patterns of governance (colonization and independence), ideologies (role of the state and other actors), stage of development, distribution of holdings and share of population involved in farming. Except for Australia and New Zealand, small farms dominate the region. Countries such as Malaysia, India, Sri Lanka, Vietnam and Indonesia also have a plantation sector comprising big and small farms.

Except for the mall island states in the Pacific (other than Fiji and Papua New Guinea), most of the countries in the ESAP have a well-established structure within the public sector for agricultural research. These function mostly under the Central and State Governments linked to the ministries or departments dealing with agriculture and in few cases under Ministries/ Departments/Councils/Foundations dealing with Science and Technology. Most of these countries have separate research centers for specific crops. Agricultural Research for the Pacific Islands is co-coordinated and implemented by the Institute for Research, Extension and Training in Agriculture (IRETA). These research councils collaborate with several of the research initiatives and networks co-ordinated by the CGIAR centres such as IRRI, CIMMYT, ICRISAT, IWMI and AVRDC. Partnering with CGIAR, international networks have contributed immensely to the capability of many of these national systems. ACIAR has also been collaborating with several of these national research councils. Most of these national systems are organized top-down, depends fully on the state for funding and with moderate to week links with extension. Inadequate technology adoption has been generally attributed to weaknesses in research-extension linkages, although several measures to address this have been taken during the last two decades (Sharma, 2002).

Public sector. Every country in this region has a department within the public sector to provide agricultural extension services to the farming community. Extension arrangements in all the Asian Countries reveal a large degree of similarity in terms of organization and underlying conceptual framework (Sulaiman and Hall, 2005). Firstly, extension continues to be planned, funded and implemented by Departments or units attached to the Ministry of Agriculture and almost all of them are organized in a top-down fashion, mainly supply driven, implementing the programmes conceived by the state with little participation from farmers and other agencies and with little accountability to the clients. As an example, several countries in the South and South East Asian Region implemented the Training and Visit System of extension in the 1980's. Extension services were decentralized in many countries. Although it has improved farmer control and made services more demand-driven, extension services have virtually collapsed as a result of weakening financial and technical support. The results have been disastrous in Philippines and Indonesia (Qamar, 2002). Secondly, technology dissemination continues to be understood as the primary and often the single mandate of extension, whereas farmers' information and support needs have changed drastically in the recent decades (Sulaiman and Hall, 2003, van den Ban, 2005). Thirdly pluralistic extension arrangements are emerging and it includes, extension by private input companies, NGOs, farmer associations, agro-processing companies and consultants.

Public sector extension arrangements have considerably weakened in most of the countries in the region in the 1990s. The only exemption is probably China, which has been expanding its extension infrastructure. The number of extension staff paid by the government and working at the township level has already reached 1 million (Yonggong, 1998). The Extension Education and communication Service of the FAO currently assists, Indonesia and Philippines to help them establish and/or strengthen their devolved extension services (Rivera et al, 2001). Only New Zealand has a fully privatized extension set-up and farmers pay for the various services. Technical contracts are signed between farmers and extension agents in China and under this arrangement, the agent and the farm household share profits and risks. Extension provided by processing companies to those growing crops under contract arrangement is quite common in several countries.

NGOs. NGOs have been playing an important role in agricultural development in almost all the Asian Countries. For instance, in Bangladesh, the Bangladesh Rural Advancement Committee (BRAC) and "Grameen", the two major NGOs have been helping the poor in developing income-generating projects through their nation-wide credit program. It provides integrated set of services to the entrepreneurs including training in improved techniques and also problem solving assistance. NGOs play an important role in agricultural development in Philippines, Nepal and India, especially in technology adaptation and dissemination. NGOs are new to Vietnam, but they have started to play an important role in agricultural development.

Farmer organizations and producer co-operatives play a wide range of services. For instance, in Australia, the Grain Growers Association (GGA) has been supporting the grains industry through direct R & D investment and historically this funding has largely been in the areas of plant breeding and grain quality testing. In recent years it is supporting research efforts aimed at developing commercially viable biological control agents and development of best management practices. It works with the research funders, primarily the Grain Research Development Corporation (GRDC) to facilitate prioritization of R & D. South Australian Farmer Federation which is more than 100 years old, lobbies actively on behalf of its members to protect the farmer interests. Agro-Enterprise Centers, set up by the Federation of Nepalese Chamber of Commerce and Industry (FNCCI) in Nepal lobbies for favorable policies for agro-business development. Farmer associations are equal partners in extension in countries such as South Korea and Taiwan. In Indonesia, the "Indonesian IPM Farmers Association" which was established in 1999, support fellow farmers in the transition to more sustainable and profitable farming (Elske van de Fliert, 2006). Producer co-operatives play an important role in extension, input supply and marketing in India (dairy, sugar, fruits etc).

In Vietnam, mass organizations, the "Women's Union" and "Youth Union" acts as a parallel delivery mechanism for welfare and credit programs and they strongly influence government policies. "Women's Union" has 12 million members and is engaged in a whole range of social welfare and development projects, which aim to improve the living standards and skills levels of women (SGTS & Associates, 2000). Media (print, radio, television) play an important role in information flow in agriculture and several countries are experimenting with use of ICTs to transfer a range of production and marketing information. Consultants are also emerging as an important source of information and advice to large growers and those cultivating high value crops and they are specially valued for customizing their advice to individual farm situation.

As mentioned earlier, apart from actors and organizations involved in RDTE, development and sustainability of agriculture depends also on the market arrangements, value addition opportunities, infrastructure (road, air links, storage, cold chains etc), availability and access to credit at reasonable terms and enforcement of standards, certification and policies that respond adequately to changing agricultural situation. General economic policies, country development plans, specific agricultural policies and plans, international agreements all determine the direction and pace of agricultural growth. Quite often these different stakeholders influence plans, programs and policies and the wider institutional environment and these in turn influence interaction and inter-relationships between different stakeholders including those outside the RDTE system.

Institutional barriers. Literature on the nature of institutions and how it shapes, facilitates and/or hinders technology developments in the ESAP region is limited. Much of the literature discusses the research-extension linkage and the challenges of integrating research and extension and that too with respect to crop production only. (Literature on research-extension linkages in animal husbandry and fisheries sector is still limited). Though research-extension linkage would continue to remain important, there is an increasing realization that organizations involved in research, development, training and extension (RDTE) need to develop partnerships with a large number of other actors (farmers, NGOs, producer organizations, input agencies, agro-processors, agri-business houses, traders, retailers and even consumers (van Mele, 2005, Hall, 2006),. Developing wider links is not only essential for improving the performance of organizations involved in RDTE but also for rural innovation to happen-where new knowledge, information and technologies are made available and is put to socially and economically productive use. Though a large number of organizations exist in most of these countries, the nature of interactions between these different organizations needs to be improved for optimum use of AKST. Several ways to improve interactions between research and extension have been tried with varying levels of success. Some of these are illustrated below. See table 5.4.

Though there is an increasing realization on the need for better interactions among the various actors, including research extension and farmers, this is not happening due to the following institutional barriers. Addressing these issues therefore needs immediate attention.

A. Linear approach to technology development and promotion: The respective roles of Research and Extension are defined in this paradigm. In this model, extension acts as a conduit for transferring technologies developed by the research systems with or without participation by the farmers. Though there is an increasing realization on the limitations of this model, it continues to be the dominant paradigm determining investments in agricultural research and extension. Administration and funding by different departments or ministries further constrain development of relationships.

B. Hierarchies: Due to the perceived hierarchy between research and extension, the process is top down with limited feedback and each one blames the other for poor performance of technology diffusion and adoption. Hierarchies also exist between biological and social scientists. This hierarchy is preventing interactions among these two groups of scientists. Social science perspectives are thereby missed in most of the technology development and promotion interventions.

C. Mismatch in expectations: While farmers, NGOs and the private sector need research and scientific expertise to solve specific problems, what research offers are pre-determined technologies. Interface meetings with the private sector haven't moved beyond the partnership rhetoric, especially due to this mismatch in expectations. While procedures for transferring technologies are in place, arrangements for providing technical expertise to solve problems haven't been fully developed.

D. Perceived role of social sciences: Economics and to be more precise, agricultural economics is considered as the only relevant social science in agriculture. This limited social science base is mostly used for setting research priorities or measuring impacts of technologies. Social science are not put to use to learn from emerging institutional arrangements or to design new institutional arrangements

E. Narrow focus of extension on technology dissemination: While producers needs a wide range of information (production, processing, prices, standards, markets, prices) and support (organizational, market development), extensions role is mainly focused on transferring production technologies.

F. Evaluation: Evaluation parameters within research organizations favour (i) technology development at the cost of problem solving and (ii) reporting only success at the cost of learning from failures and (iii) favour reporting only technical innovations at the cost of process and institutional innovations that facilitated development and promotion of technologies. Similar is the case within extension where performance is evaluated in terms of number of farmers adopting a specific technology, inputs distributed and increase in productivity that has been achieved. This restricts extension staff from trying other promising approaches that could potentially increase farm incomes.

G. Only farmers as clients: Focusing only on farmers as clients have restricted the interaction of research and extension to farmers only at the cost of interaction and working with a range of other actors like NGOs, agro-processors, traders, private sector and producer associations.

H. High levels of mistrust: Interaction among the different actors are further constrained by the high levels of mistrust between the different actors (public and private; private and NGOs etc) and lack of mechanisms to develop better understanding. Though some of the public, private and NGO actors have come together as part of specific initiatives promoted by donors, this has been restricted to the particular project duration. Levels of mistrust are too high between NGOs and the private sector and lack of transparency in conduct of research and inability of science to communicate to different stakeholders have further contributed to decline in trust.

I. Centralisation: (funding, management and evaluation) Long chains of command and control constrain the ability of the different organizations, especially the private sector to respond quickly to the challenges from the field (or market). This is also constraining development of joint activities even when the policy favor partnerships.

J. Accountability: The current patterns of funding and governance (mostly public) ensure that the organizations are only accountable to the Ministry/Department funding and governing them with only weak or limited accountability to the clients. Companies in the private sector also behave as if they are only accountable to their shareholders and not to other stakeholders who can potentially influence their operations

Addressing these institutional barriers is therefore important for achieving the developmental and sustainability goals of AKST. Organizational reforms within public sector Research and Extension organizations such as decentralization and interface meetings with wide range of stakeholders hasn't really changed the underlying paradigms governing the way Research or Extension is implemented in the region. Similarly having a sound policy doesn't ensure better performance. The policy should facilitate change, through a process of experimentation, reflection and learning so that it develops the capacity of the various stakeholders to identify bottlenecks, experiment alternative way of working, evaluate performance, learn and design better strategies.

There is a case for implementing a series of institutional changes (ie changes in rules, norms, conventions and habits within these organizations and the way it relates to other stakeholders) in the RDTE system and others related to RDTE if the governments are keen to improve the performance of this system. This has to be a learning based approach appropriate to the specific institutional context and this process needs to be facilitated. One way of dealing with this issue is to examine the emerging institutional arrangements and learn lessons from them.

Innovative institutional arrangements. Many of these innovative institutional arrangements have emerged in response to new demands and in most cases restricted to few sectors, organization or countries. Many of these could be relevant for others albeit with suitable modifications.

New patterns of interaction. Since the early 90's there has been an increasing realization among the research management (especially within CGIAR and NARS) on the need to (i) work with actors beyond their traditional partners (scientists in other CG centres or NARS) and (b) engage beyond token consultations in the research process. This has led to the development of wider networks and consortia with members from the private and NGO sectors. Rice IPM Network of IRRI is one among the several such examples. Another case is ICRISAT, which in 2000 signed agreements with a consortium of private sector seed companies to develop sorghum and pearl millet hybrid parents. This was the first time where a private consortium had made grants to ICRISAT to support two research projects that were in the interests of both the private consortium and the public-good mandate of the Institute (Reddy et al 2001). Since 2000, ICRISAT has been partnering with a broad range of actors, (consortium approach) namely NGO and government departments in watershed research programmes. (Industry and farmer association funding public sector research is however not new for countries such as Australia and New Zealand). The Indian Council of Agricultural Research (ICAR) in 1997 established (i) a mechanism to provide its services on a consultancy and contractual basis and (b) initiated measures for making available germplasm and other technology products of ICAR to the private sector at nominal cost.

Wider role of NGOs. Those actively working with the small farmers and the rural poor have long recognized their importance of provision of an integrated set of support for the poor. One such organization is the NGO, the BARC in Bangladesh. The projects/enterprises covered by BRAC include poultry, animals, nursery, fisheries and other small business. BRAC has poultry farms and hatcheries, poultry disease diagnostic lab, bull stations, feed mills, fish and prawn hatcheries, and nursery for supply of planting materials and seeds. It has also received the EUREGAP certification for export of vegetables and has a vegetable export programme. It also has a dedicated extension programme for vegetable cultivation and for promotion of crop diversification. Most of these initiatives rest on the thrift and credit groups of the poor served by the micro-credit which itself has been a new institutional innovation.

Farmer Field Schools. Though initiated mainly to address the pest problems in rice, the farmer field schools has turned out to be a platform for joint learning (in several Asian countries) by the various stakeholders for solving problems that need community participation. Most of the emerging challenges in agriculture, related to introduction of new crops and engagement with new market channels (contract growing, quality management, certification etc) needs community mobilization and joint learning. Continued learning, problem solving and collectivity, as supported by the FFS, albeit with a changed content focus remain important. (Elske van de Fliert, 2006). There is a need for mainstreaming of this approach and reduce its dependence on external funding.

Contracting arrangements in farming. Though not a new arrangement per se, the scope of contractual farming arrangements have been widening in terms of commodities and range of services. With opening of markets and emergence of supermarkets, the need for a reliable supply of quality produce in distant and often high value markets became essential and several agro-processing companies and supermarket chains have entered into this sector. Many of these companies provide seeds, inputs and credit to the participating growers and procure the produce from them at pre-determined prices. They also bring in new technology and provide advice to growers. Though the arrangement looks promising, lack of proper legal framework to ensure contracts and lack of shared agreement on quality standards and prices have been hindering expansion of this arrangement. For farmers to gain advantage, their ability to understand contracts and negotiate better arrangements needs strengthening.

There is an increasing concern on the contract farming operations by the corporate sector. Critics of the “co-orporate farming”, point out that “even in developed countries such as the US and EU, the agricultural co-operatives hold dominant markets shares” Studies have clearly demonstrate that between 60-75% of the market share in grain trade is held by the agricultural cooperatives in Denmark, France, Ireland, Austria and Sweden. Even at the peak of the corporate engagement in agriculture in the US, the agricultural cooperatives have been able to slice a 38% share of the market in trading grains alone (Sharma, 2006). While contract farming arrangements are becoming increasingly essential, to protect the producers as well as the consumer, keeping in view the nature of small holdings and low capital base in several parts of Asia, contract farming by producer co-operatives looks more promising. “Producer companies” is the new institutional arrangement that has come up in India and Sri Lanka as a response to address the new challenges and the old problems with the producer co-operatives.

All these new arrangements indicate the need for new ways of working to meet the emerging challenges and one of the greatest challenges for the RDTE is in making the needed reforms to respond faster. It is now widely recognized that for agricultural research to remain relevant it needs to go beyond restructuring within the confines of the old agricultural research system model-although these may be an important starting point (Byerlee and Alex 1988). But changes are needed not only in the research organizations, but also among the wide range of actors and organizations in RDTE and outside that influence development and sustainability of agriculture. Considering the huge institutional barriers discussed earlier, this is not going to be an easy task.

Partnerships toward development and sustainability goals. Donors and policy makers increasingly recognize partnerships as a viable strategy for agricultural development and poverty reduction. The potential advantage of partnerships is clear: the pooling of diverse expertise, leveraging scarce resources and it provides opportunities for all partners to learn new competence. In agricultural research and extension systems around the world, the respective roles of the public and private sectors and the relationship between them are changing (James, 1996; Hall et al, 2002, Byerlee and Echeverria, 2002, Speilman and Grebmer, 2004, Hall, 2006). Two main factors namely, the increasing number and range of actors outside the public sector and the increasing complexity of agricultural development that necessitates integration of efforts of several partners with complimentary skills have contributed to the realization on the need for partnerships. Declining financial ability of states to invest in research and extension and the re-evaluation of the role of the state in research and extension have also contributed to the shift towards privatization of public services and development of public-private partnerships. Though all have realized the importance of partnerships, there are not many cases of public-private partnerships in agricultural research and extension. Partnership is still an exception, usually promoted by a specific project or program funding, though the number and types of private, NGO and community based organizations have increased considerably over the last one decade.

CGIAR-NARS partnership perhaps could be the only case of a long-standing successful agricultural research partnership in Asia. Apart from training scientists from developing countries, this partnership has led to development of several new technologies. Agricultural scientists of NARS partnering with their counterparts in the CG system or other NARS centers have become quite common. Agricultural research has also gradually moved towards embracing multi-disciplinarily. Farming Systems Research and Farmer Participatory Research to a certain extent forced researchers to partner with farmers, though much of this relationship has been top-down and restricted to the tail end of the research process. Partnering with the private sector and NGOs in technology development and promotion initiatives became an important strategy only towards the 90s. In 1995, CGIAR for the first time established a private sector committee to improve its dialogue with the private sector and facilitate collaboration. Later it formed the NGO Committee for pursuing similar goals. The establishment of the International Service for the Acquisition of Agri-Biotech Application (ISAAA) in 1991 was another important landmark. It was created to transfer agri-biotechnology applications from industrial countries in the North, particularly proprietary technology from the private sector, to developing countries. Papayas Biotechnology network for SE Asia (Indonesia, Malaysia, Thailand, Philippines, and Vietnam), Development and transfer of Insect resistant sweet potato in Vietnam and Development of Virus resistant sweet potato in Philippines are considered as successful cases of public-private partnerships promoted by ISAAA.

In the year 2000, ICRISAT signed agreements with a consortium of private sector seed companies to develop sorghum and pearl millet hybrid parents. This was the first time where a private consortium had made grants to ICRISAT to support two research projects that were in the interests of both the private consortium and the public-good mandate of the Institute (Reddy et al 2001). Since 2000, ICRISAT has been partnering with a broad range of actors, (consortium approach) namely NGO and government departments in watershed research. In several countries, organizations under the NARS have been partnering with NGOs in technology promotion activities. The Rice-Wheat Consortium (jointly promoted by CIMMYT and IRRI) is currently working with the private sector input and service providers, agricultural machinery manufactures and NGOs in the promotion of zero-drill. Spread of Systems of Rice Intensification (SRI) is a classic case of civil society led technology promotion. Partnership arrangements with farmer organizations for technology promotion activities are also quite common. Partnering with private sector life science companies continues to remain problematic, due to conflicting goals and lack of transparency.

Patterns of interaction between public and private sector in agricultural research can be broadly classified under three areas: This include a. private distribution of public technologies, b. private purchase of public research services and technologies and c. public private research partnership (Hall, et al 2002). While the fists two are relatively easy to implement and manage, developing research partnerships has always been difficult. Public-private partnerships are significantly constrained by insufficient accounting of the actual and hidden costs of partnership; persistent negative perceptions across sectors; undue competition over financial and intellectual resources; and a lack of working models from which to draw lessons and experiences (Spielmen and Grebmer, 2004). The ongoing and still unresolved disputes on IPR and GMOs have further made public-private partnership in agricultural research increasingly difficult. Donor pressures have forced several agricultural research organizations to embrace partnership. But partnership is yet to become an organizing principle for technology development and promotion in developing countries in Asia. However in Australia and New Zealand, farmer (farmer organization) funding for R and D has provided an appropriate framework for partnership between research and farmers.

However, a different kind of partnership is emerging very strongly in ESAP region. Many of the NGO groups in Asia are increasingly partnering with several other NGO groups, farmer groups and activists to form alliances and networks, especially to counter the introduction of policies and technologies, which they consider as detrimental to farmer interests and to promote alternatives. For instance, PABINI in Philippines is a network of farmers and supportive academics and researchers for sustainable agriculture, organic farming and farmer-selected seeds. PABINI in collaboration with several other organizations oppose the introduction of GE technologies. There are a large number of global and regional networks whose members' partner in joint struggles against certain technologies and policies. Pesticide Action Network and the Third World Network etc are some of the successful networks, with partner organizations in different countries. These kinds of partnerships are expected to grow and influence the development and sustainability of agriculture. Organizations in RDTE, instead of neglecting their existence, need to engage with these different groups and networks. Public-private partnerships in extension are only staring to emerge. Farmer organizations are equal partners in extension in South Korea and Taiwan.

Partnering continues to be a difficult proposition for many of the organizations in RDTE across ESAP, which are used to working in isolation for the past several decades. The linear model of technology development and promotion (Research-Extension-Farmer) continues to set the patterns of interaction, though it has not much relevance in the contemporary scenario. For successful innovation process (development, adaptation, diffusion and use of agricultural technology leading to economic and social benefits), research and extension agencies need to partner with the wide range of actors/organizations is essential. These include agencies such as banks, producer groups, equipment manufactures, transporters, input agencies, market intermediaries, policy system, and other service providers. Frameworks such as "innovation systems" seem to offer solutions for reconfiguration of the roles of the different actors. Box 5.1 synthesizes the lessons from analysis of partnership experiences from the crop post-harvest sector of South Asia.

Some of the key recommendations that emerged through a joint analysis by the different stakeholders who have participated in four NRM projects in India is given in Box 5.2. The projects examined include: a integrated management of land and water resources (DFID/NRSP-ICAR), b. improved livelihoods through a consortium approach (ICRISAT) c. Promoting zero-tillage (Rice-Wheat Consortia) and d. Community development (Aga Khan Rural Support Project). All those interested in promoting partnerships in RDTE may find these very relevant. See Box 5.2.

In conclusion, there cannot be a blue print for promoting partnerships, but development of partnership arrangement could be facilitated. Funding for agriculture could be potentially used to facilitate development of partnerships. The options range from supporting stakeholder meetings to handholding development of joint collaborative activities. But these have to be supplemented with efforts to reflect on progress and outcomes and the vision and willingness to make needed institutional changes.

Some of the potential ways for enabling institutional changes are listed below:

1. Learning from the emerging institutional arrangements in the region. This would necessitate a detailed analysis of cases where the various actors in specific contexts came together and collaborated to solve particular problems or address new challenges. What kind of institutional changes were made and also understand how these changes are sustained or why these couldn't be sustained after the end of the specific initiative?

2. All organizations do not have a culture of learning. Opportunities needs to be created and if need be specifically funded to bring in this change of culture. It would be useful to bring the staff together to reflect on the past, what they learnt and what needs to be done to do the same job better? The concept of institutional learning concerns the process through which new ways of working emerges. It concerns learning how to do things in new ways. It specifically asks the questions, what rules, habits and

conventions have to be changed to do a new task or to do an old one better? (Hall et al, 2005)

3. Create opportunities to bring different actors together and develop joint activities. These can potentially help in developing long term relationships. Development of joint collaborative projects needs to be mentored over a period of time and need specific resources. Funding could be potentially used to facilitate development of joint collaborative projects.

4. Using better framework of analysis such as "innovation systems approach"- to analyze the patterns of interaction and as a framework for planning interventions (World Bank, 2006). This would necessitate detailed exploration of the innovation systems and organization of capacity development programs.

5. Organize "Capacity development" programs to address the institutional barriers

2.3.3 Traditional and local knowledge systems

For people engaged in agriculture, the systems and practices used and developed collectively through generations by farming and indigenous communities in managing their crops and animals, including the forest and water ecosystems, to respond to the specific needs, conditions, and changes evolving within the locality are included here. As such, they are also considered dynamic because while these systems innovate from within, they also adapt and incorporate new knowledge from outside to suit gradually changing environments.

Through the years, local and traditional knowledge has played an important part in maintaining and improving the livelihood of farming communities—from producing food and providing shelter, to achieving control of their lives. In fact, it has become the basis for local-level decision-making not only in agriculture, but also in health care, food preparation, education, natural resource management, and a host of other activities in rural communities (Warren, 1991). In addition, local expertise in agricultural technologies has significantly contributed to global knowledge.

Crops and medicinal plants. Traditional knowledge has evolved in response to the pressing concerns of farmers and indigenous people over their environments. Before modern agricultural knowledge and practices were developed, local communities had already devised methods for ensuring the success of their agricultural endeavors. In cropping, traditional knowledge may include (Grenier, 1998):

- indigenous indicators to determine favourable times to prepare, plant, and harvest gardens;
- land-preparation practices;
- indigenous ways to propagate plants;
- seed storage and processing (drying, threshing, cleaning, and grading);
- seed practices;
- indigenous methods of sowing (seed spacing and intercropping);
- seedling preparation and care;
- farming and cropping systems (for example complementary groupings);
- crop harvesting and storage;
- food processing and marketing; and
- pest management systems and plant-protection methods.

One common example of traditional knowledge emanating from communities is the use of the neem tree (Azadirachta indica) as a natural insecticide and fertiliser. For centuries, farmers in India have been using the ground seeds of neem against insect pests in the field, while the leaves are used to protect grains stored in local containers (Davis, 1998). Now neem has been commercialised into a modern biopesticide used in many countries.

In Nepal, hill farmers have a ranking system for the nutrient value of manure from different animals in terms of its use as fertiliser—from bat to buffalo—which corresponds well with the scientific findings based on macro-nutrient content (Tamang, 1993 as cited by Andersen, 2000). The knowledge of this range of indigenous practices of crop protection and fertilisation can be appreciated when developing appropriate programs for pest and soil management that are within the capabilities of farmers, and do not cause adverse effects on either the community or the environment (Varisco et al., 1992).

Indigenous and traditional knowledge and practices are important in attaining food security as well as conserving genetic diversity. In Nepal, a centuries-old seed management system has allowed farmers to continuously grow and protect their seeds (Ghale and Upreti, 1999 as cited by Timsina and Upreti, 2002). For instance, farmers use intercropping, crop rotation, and crop intensification for seed security purposes. They also employ multiple cropping to minimize total crop failure. Indigenous post harvest management systems like storing the cleaned and dried seeds in clothes, earthen pots, tin and bamboo materials, and hanging dried spikes wrapped in plastic in an open protected area are commonly practiced. Placing several herbs and mixing different type of grains (i.e. maize and millet), as a means to protect the stored seeds and maintain storability and quality, have proven effective in ensuring that seeds are kept and passed on from one generation to another (Timsina and Upreti, 2002).

In addition, modern plant breeding also owes so much to the landraces bred, conserved, and developed by traditional communities over the millennia. These local varieties have been the continuous source of genes used in the development and improvement of high yielding varieties. Before modern agricultural scientists arrived on the scene, conservation and innovations with plant genetic resources by farming communities had already been practiced for about 100 years (Hossain, 2002).

On the other hand, traditional knowledge of crops has also contributed greatly to modern medicine and biopesticides. For example the neem tree (Azadirachta indica), which has been widely used in India, appears to be effective against malaria and internal worms. To maintain personal hygiene, neem was reportedly used by 500 million Indians in brushing their teeth, as well as for making soap. Another example is the Conospermum, commonly called smokebush in Australia, used traditionally by Aboriginal peoples for a variety of therapeutic purposes. In the late 1980s the plant was found to contain a substance called Conocurvone, reported to be a potential cure for AIDS (Davis, 1998).

In fact, it is estimated that, in 1985, US $43 billion worth of plant-based medicines (many of which were used first by indigenous peoples) were sold in developed countries (Principe, 1989 as cited by Posey and Dutfield, 1996). As advances in biotechnology broaden the range of life forms containing attributes with commercial applications, the full market value of traditional knowledge will certainly increase.

Livestock. Similarly, indigenous and traditional knowledge and practices in animal agriculture systems include (Grenier, 1998):

- indigenous methods of animal breeding and production;
- traditional fodder and forage species and their specific uses;
- animal-disease classification; and
- traditional ethno-veterinary medicine.

In India, the importance of animals goes beyond agriculture: it is not only a part of the farming system but is also closely linked with religion and culture, and management systems need to be understood in that context (Rangnekar, 1994). Indigenous technical knowledge in animal husbandry is considered as old as domestication of various animal species. A recent study in

India has revealed that traditional health control and treatment systems were effective in curing a number of ailments in animals including dysentery, arthritis, dog bites, coughs and colds, anoestrus, wounds, bloat and diarrhoea. And although modern veterinary medicines were found to give a quicker cure than traditional treatment and preparations, nevertheless, the latter are cheaper, more locally available to farmers especially in remote areas, and with lower side effects than the former (De Amitendu et al., 2004). This finding is even more significant in light of the fact that most of the communities engaged in the animal agriculture industry live in marginal areas that are not easily accessible to modern veterinary information and services. The survival mechanisms therefore are simply based on the local and inherent centuries old knowledge that has withstood the test of time (Wanzala et al., 2005).

In another study in north Gujarat and south Rajasthan in India development strategies, to improve feeding and management practices suitable for more productive animal agriculture systems, were formulated as a result of information gathered from women tending animals in the area. The results showed that local women possess valuable information about local feed resources and a working knowledge of animal behaviour, feed preferences and production characteristics and that, through experience, they have developed feeding practices that suit different types of animals, identified beneficial feed resources ranging from farm by-products to forest products, and developed ways of conserving useful feed materials during periods of scarcity (Rangnekar, 1994).

Forestry. Indigenous peoples have practiced sustainable forest utilisation and management techniques for centuries. Indigenous knowledge in forestry includes (Grenier, 1998): management of forest plots and their productivity; knowledge and use of forest plants (and animals); and understanding of the interrelationships between tree species, improved crop yields, and soil fertility.

A study by Jackson and Moore emphasises the role of indigenous people and practices, particularly the traditional use of fire in forest management and conservation. The study argued that although forest fire is often perceived as destructive, nevertheless, the indigenous use and management of fire plays a significant role in shaping forest ecosystems, that is, for regeneration of landscapes, facilitation of crop production, pest control, and prevention of unplanned or out of control burns (Jackson and Moore, nd). For instance, annual fires as practiced by local people in Sumbawa, Indonesia are intended to maintain grasslands in a condition that favours grazing animals and enable the population of wild herbivores to be maintained at higher levels than they would be without fires. Similarly, in Nepal, local communities use fire extensively to promote regeneration of grass for animal agriculture. In central and northern Australia, aboriginal communities have sophisticated applications of fire that take into account seasonality, patterns of burning, specific effects on wildlife and plants, and exclusion of fire from particular areas and vegetation types (Braithwaite, 1991 as cited by Jackson and Moore, nd). Aboriginals also use fire to encourage regrowth of grasses for target wild animal species (especially kangaroos and wallabies).

Another example of the importance of traditional knowledge in forestry is the unique systems of managing natural resources and forests of the indigenous Hani communities in Mengsong, Xishuangbanna, in Yunnan province of China. These communities have developed a system of classifying forests and forest systems according to their function and products, such as forests that produce building materials (lieshugejo) or cash crops (naqiluogo), forests that enhance the landscape (puchang), forests used for graveyards (nagbiong) and protected rattan forest (Sangpabawa). They also employ a selective management of rattan and other plants, which protects biodiversity and maintains the natural water situation.

In Sri Lanka, forestry has traditionally been combined with cropping and animal rearing, as for example in the classical Kandyan Forest Gardens. Here the agricultural system simulates a tropical rain forest, but on small land units averaging about 1 hectare in size. It consists of a mix of as many as 30 perennial and semi-perennial trees and shrubs (ESCAP, 2002). The farmers who practise this system are reported to enjoy a relatively better living because of returns from both cash crops and subsistence products, and improved health and longevity (Jacobs and Allen, 1987 as cited in ESCAP 2002).

Aquaculture and fisheries. Aquaculture systems integrated into cropping systems and utilizing traditional practices—such as the rice-fish systems in Bangladesh—can contribute to food security and food diversity (Pretty and Hine, 2001). They can also provide other benefits: for example the introduction of larva-eating fish into rice fields in Quanzhou County, Jiangsu Province, China has increased rice yields, reduced pesticide use and significantly reduced the incidence of malaria (Pretty and Hine, 2001).

In general, there is a growing realization that indigenous knowledge and traditional agricultural systems have a great deal to offer in terms of genetic resources, food, medicine, clothing, shelter, tools, techniques, and crop and animal protection. They possess two powerful advantages. First, these systems are often inexpensive to implement, and can frequently be paid for in goods or services. Second, they are readily available and accessible even to those who do not have cash incomes. In most cases indigenous knowledge systems and technology are socially desirable, economically affordable, sustainable, involve minimum risk to rural farmers, and producers, and often conserve natural resources. Since they evolved gradually within the community and under its control, they are considered appropriate to the needs of the local people (Appleton, 1991 as cited by Rouse, 1999). Indigenous knowledge systems therefore are more directed towards self-reliance and self-sufficiency than are modern technologies imposed from outside (Fernandez, 1994).

Although traditional agriculture was able to feed people over centuries under a range of bioclimatic conditions, it could not keep pace with the significantly increased population pressure, as witnessed by the great famines of the 1950s, 60s, and 70s in China, India and Bangladesh, for example (ref Medha). But although traditional systems, for example of rice production, appear to be unable to provide a sufficient quantity of food for current urban populations, it would be a mistake to view these systems solely in terms of their monocultural output for the commercial market. For they are generally able to provide a diversity of products that may be of equal or greater total biomass production per unit of area than conventional equivalents whilst conserving scarce resources, and providing food security to the actual producers (FAO, 2002). And, generally, the greater the biological diversity of the agricultural system, the greater its ability to withstand adverse climatic and pest events (FAO, 2002). Additionally, according to the ESCAP (2002) report, there is historical evidence of wetland rice yields in India being higher than present day yields in systems using chemical fertilisers and pesticides. In the 18th century the yields in 800 villages near Madras were reported to average 3.6 tonnes per hectare and surpassing 10 tonnes per hectare in some, whereas the current yield in that region averages are 3.1 tonnes per hectare. Genetic diversity was the main weapon against pest and diseases, but now India's previous approximately 30,00? varieties of rice have been eroded down to a handful, with 75% of the rice produced from just 10 varieties.

Traditional agriculture is very labour intensive, and this may be seen as either a disadvantage or advantage depending on the social circumstances. For example the additional labour requirement may keep people from engaging in other economic activity if it is available. On the other hand it can provide meaningful employment for those rural people who would otherwise migrate to urban areas, creating diverse social effects such as leaving behind a household without its male head and potentially contributing to urban unemployment and poverty.

Today about 70% of the world's indigenous peoples live in Asia and the Pacific, and in all countries in the region indigenous peoples are a major subgroup of the rural poor. The marginalisation and poverty of many indigenous communities is closely linked to their being deprived of the ability to lead the kind of lives they value (IFAD, 2002a). Maintaining and improving the productivity of indigenous agricultural systems is integral to ensuring the sustainability of these communities into the future, and in improving their health status.

Indigenous knowledge and traditional agricultural systems have much to offer in the future development of sustainable agricultural systems, and the role they play should be in response to the specific needs and conditions of farmers to maintain food security and improve micronutrient content of food with minimal human and environmental health consequences, taking into account gender equity and equitable access to resources.

Crops and medicinal plants. Organic agriculture employs a range of cropping techniques that essentially aim to replace external chemical inputs with ecosystem functions (FAO, 2002). This means that organic management techniques are devised to support an integrated and holistic agro-ecosystem, which does not favour the growth of weeds, pests and diseases, but does enhance favourable biological activity. It fosters beneficial processes and interactions such as occur in natural ecosystems, encouraging internal stability rather than relying on external control measures. It aims to recycle nutrients, conserve energy, soil and water resources, and preserve biodiversity (BIO-GRO, 2001).

The development of good soil structure, biological activity and fertility is central to organics, as it is crucial to good plant health which in turn is important in resisting pests and diseases. In fact, comparisons of soil under conditions of organic management and conventional management in kiwfruit orchards in New Zealand revealed that the organic orchard soils had higher pH, higher soil cation exchange, more calcium and magnesium, more potentially mineralisable nitrogen, and biomass carbon, although lower phosphate, greater size and activity of the microbial population, and greater earthworm populations (Pearson et al., 2005).

Organic cropping techniques include (BIO-GRO, 2001):

- selection of crops and varieties that best suit the climate and agroecological system, and have disease resistance or tolerance;
- management of planting dates;
- crop rotations, including farrowing and herbal leys;
- intercropping and use of undercrops for weed control and beneficial insects habitat;
- solarisation;
- animal manures, green manures especially legumes, turning in of crop residues, composts, and use of effective microorganisms;
- mulches;

- hand and mechanical cultivation, but with minimal tillage;
- if necessary the use of approved mineral-bearing rocks and foliar fertilisers as an adjunct to the return of nutrients in organic matter;
- biological pest management such as biopesticides like neem, and parasitic insects;
- mechanical barriers;
- grazing by animals to control weeds and enhance fertility.

The FAO warns that comparison of yields between organic and conventional systems are only meaningful over a period of time as high yields in the later are often based on “exploitative systems that degrade land, water, biodiversity and ecological services on which food production depends” (FAO, 2002, p8).

Conversion to organics from high-yielding conventional systems often results in a drop in gross yield of the marketable commodity, the degree of drop varying considerably, whereas conversion from low-input, often traditional systems can raise productivity by optimising the use of local resources (FAO, 2002; IFAP, 2002). Additionally, conversion to organics in medium-potential areas in the tropics can show good performance (FAO, 2002).

There are a number of organic conversion projects in the Asia Pacific region that have reported good yield increases as a result of conversion to organics, for example:

- In a comparison between organic and non-organic strawberry production in Guangming village, Jiangsu Province, China, the second and third years of production resulted in the organic system yields being 29% and 11.2% respectively higher than the yields from the conventional system. Net income was increased and non-renewable energy use decreased (Xi et al., 1997 as cited in FAO, 2002).

- In Nepal, a community welfare and development project involving 600 farm households in organic production, cultivating 250 hectares, reported increased maize and rice yields, the planting of new vegetable crops, and improved health and nutritional status of the farming household, especially the children (FAO, 2002).

- Also in Nepal, the Jajarkot permaculture programme, involving 580 farm households on 350 hectares, reported rice yields increased from 1.8 to 2.4 tonnes per hectare and maize yields increased from 1.2 to 1.6 tonnes/hectare. There is also greater tree cover and biodiversity as a result of agroforestry, providing greater resistance to drought (FAO, 2002).

- In Pakistan, the Sindh Rural Women's Uplift Group, which involved 5,000 farm households with 2500 hectares under organic cultivation, reported that mango yields increased from 7.5 tonnes to 22.5 tonnes per hectare, and citrus went up from 12 to 40 tonnes per hectare. There has been a 2- to 3-fold increase in food security (FAO, 2002).

- In the Kamarajar District of Tamil Nadu, the Society for People's Education and Economic Change's project based on organic agriculture has reported increased yields and a number of social benefits. The sustainable approaches adopted included improved water harvesting that has allowed the cultivation of previously abandoned dry land, an additional wet rice crop on irrigated land, and the introduction of milk cows. Sorghum and millet yields have doubled, and extra crop, fruit and timbers trees are cultivated. These efforts in turn have resulted in new health care provisions, road building, and savings and credit schemes (FAO, 2002).

- The case study of an organic sugar cane cultivation system in Belagun, Karnataka, India, illustrates a number of features about organic systems, both positive and negative. The farmer uses a no-till, alternate row irrigation approach, with the cane trash recycled and with green manuring to increase fertility. His yield of sugar cane is 100 tonnes per hectare compared with the neighbouring 110 tonnes, but the input costs are much less. There has been a 76-80% reduction in irrigation, labour requirements are reduced by 30%, the cane matures in 8-9 months instead of 11-12 months, and the net profit is increased. Importantly, the farmer does not have to outlay as much money for inputs, reducing financial risk in the event of crop failure (FAO, 2002).

Livestock. In organic agricultural systems that are similar to traditional approaches to agriculture, animals are incorporated into a mixed animal agriculture/cropping enterprise, often with the addition of forestry in the form of agroforestry. At the other end of the spectrum are large mono-animal enterprises, such as can be found in the dairy industry in New Zealand. To the unpractised eye these may look like conventional farms. The difference lies largely in the organic management of pasture, appropriate disposal of manure, inputs that are permitted to be used, as well as practices that affect the animals' ability to express their innate behaviour.

Organic animal agriculture practices include (BIO-GRO, 2001):

- soil management techniques based on appropriate stocking rates and sympathetic grazing regimes to minimise damage to soil structure and compaction;

- provision of good quality drinking water;
- provision of organically grown feed;
- giving all animals conditions of life that allow them to perform all aspects of their innate behaviour, including free access to graze and range on a wide variety of pasture and browsing species;
- adequate housing to ensure the animals' welfare and well-being;
- using natural heath remedies as much as possible, with resort to synthetic veterinary medicines as a last resort to prevent suffering.

Intensive raising of animals on feedlots and battery cage confinement of hens are not permitted in organics.

Yields from organic dairy systems in New Zealand average around 5% lower than their conventional counterparts with higher returns and lower input costs resulting in little change in overall returns to the farmer, with the level of returns projected to increase as consumption of organic dairy products increases (Christensen and Saunders, 2003).

Forestry. Generally the production of trees in an organic system is as part of a mixed cropping, animal agriculture and forestry enterprise known as agroforestry. Often the trees will be grown for a variety of uses, rather than a single purpose: timber, fuel, fodder, even fruits and medicinal products. In the permaculture programme in Jarjrakot, Nepal, mentioned earlier, the trees in the system not only increase the biodiversity but also provide benefits in terms of greater resistance to drought (FAO, 2002).

Aquaculture and fisheries. Organic aquaculture has lagged behind the development of other kinds of organic agriculture. Organic aquaculture can take place in freshwater, brackish water and in the sea, producing fish, crustacean, molluscs and plants. New Zealand is one of the largest producers outside of Europe, with one salmon farm producing 500-800 tonnes of organic salmon. Other organic aquaculture in the region includes shrimps in Indonesia, Viet Nam and Thailand, mussels in New Zealand, and salmon in Australia. One constraining factor is the sourcing of acceptable nutrients for the farmed species (FAO, 2002).

Conventional shrimp farming in Southeast Asia has caused a great deal of concern regarding negative social and environmental effects, and the challenge for organic aquaculture is to provide much-needed protein-rich food without creating these negatives externalities. It requires that the food for the farmed species is obtained from sustainably managed fisheries, derived from locally-available fishery products not suitable for direct human consumption, free from synthetic additives and contaminants, and only fed to farmed aquatic species with naturally piscivorous feeding habits (FAO, 2002). However FAO concludes that with the “introduction of appropriate water and nutrient management techniques, the prospects for the increased production of farmed organic aquatic plants and molluscs is considerable” (FAO, 2002, p172).

2.3.4 Capacity of the existing AKST systems and itseEffectiveness for generating, disseminating and adoption

About half of all recent gains in crop yields are attributable to AKST particularly on genetic improvements targeting the physiological yield potential of crop plants and their tolerance to biotic and abiotic stresses (ref Medha). Not only did productivity increase as a result of these improvements, but yield per unit area was increased and this resulted in some positive impacts in some countries, beyond the agricultural system per se. In India for instance, less land devoted to agricultural crops resulted to an increase in the conservation and expansion of forests and woodlands by 21% between 1963 and 1999 (USDA, 2003).

Additionally the adverse environmental and health effects of the green revolution technologies have now become well recognized. The use of pesticides has had significant impacts on farm family health, which remain unquantified. There have been negative impacts on beneficial insects and wildlife, loss of biodiversity, an evolving pest complex, and agrochemical pollution of waterways. The Asian Development Bank has estimated that about one third of Asia’s agricultural land has been degraded over the last thirty years through water-logging, salination, erosion and desertification (Kaosa-ard & Rekasem, 1999). Many farmers entered a spiral of debt precipitated by rising costs of inputs and falling prices for outputs: rice farmers in the Philippines were found to be economically better off before they shifted away from the mixed cropping enterprises to the high-yielding monocultures (ESCAP, 2002; IFAD, 2002).

However, one failing of the Green Revolution is that it did not result in an equitable distribution of the benefits, with resource-rich farmers benefiting more than poorer ones. Although risk of crop failure is generally lower with conventional practices, the risk of disease outbreaks is higher. The economic outlay required for seed and pesticide and fertiliser inputs to maximize success is high, and translates to a greater risk undertaken by farmers with much to lose if crops should fail. Conventional technologies too often did not focus on ways to achieve increased food production in a resource-efficient manner that is environmentally benign.

The challenge for post Green Revolution agriculture systems is to improve productivity without the negative ecological and social side effects experienced during and after the Green Revolution, particularly improving the food security and sustaining the livelihoods of the rural poor as well as providing food for the urban populations. It needs to address the problem of diminishing supplies of oil and escalating prices of fuels and petrochemical products such as fertilisers and pesticides, finding ways to minimise these inputs – for health and environmental reasons as well as economic reasons. It needs to move to wards reduce irrigation practices as water supplies becoming increasingly scarce and oversubscribed, and to find ways to replenish the degraded agricultural soils.

2.3.5 Investments in AKST

Numerous documents have shown that agricultural research can indeed generate high rates of return-on-investments (ROI) across countries and commodities. However, funding for AKST within ESAP, with the exception of some developed economies, is generally characterized as being perennially dismal and declining if not outright stagnant with the public sector shouldering bulk of the agricultural R&D expenditures. Recently however, during the period, 1985-1995, private investments have been growing in ESAP's three largest countries-China, India and Indonesia (Pray, 2002). In the smaller Southeast Asian economies- Malaysia, the Philippines and Thailand- public research grew more rapidly than private research. At the end of the period, the private sector accounted for at most 22% of total agricultural research in these countries. Multinational corporations conduct almost half of the private R&D in developing countries of Asia, mostly dealing on breeding, pest control and processing where they can generate IPR privileges. In India, Australia and New Zealand, private producer co-operatives have also started investing in research and are also partnering actively with NARS and CGIAR. For instance, the Vasantdada Sugar Institute set up by the sugar co-operatives in Maharashtra conducts research on various aspects of sugar cane cultivation and sugar processing. Partnering with NGOs and others for technology evaluation, adaptation and update is increasingly becoming a practice in the CGIAR centers such as ICRISAT and IRRI.

2.3.6 Current developments in AKST in the region

Traditional knowledge is increasingly becoming acceptable to the scientific community. In fact, new paradigms in agricultural extension programs have recognized that local people conduct research in their own farms although it may not be in the same formal and rigorous way as employed by formal institutions like having statistical designs, replications and analysis. It is even argued that their experiential knowledge is derived from their skills as experimenters (Stanley and Rice, 2003). In addition, many technological projects failed as a result of lack of knowledge and understanding of the local practices of the beneficiary community. On the other hand, technologies generated by the formal research institutions can complement and sometimes improve existing indigenous methods.

Multiple role of agriculture. Traditionally, agriculture has been viewed for its ability to produce food, fiber and meat. However, this limited understanding of the actual roles and potential contribution of agriculture, particularly paddy farming, which has created an artificial yet highly stable economic landscapes has brought about many forms of land degradation/depletion and ecological destruction in the past. Paddy farms represent an artificial wetlands that are primarily intended to satisfy basic food and other human needs. Unknown to us however is that paddy fields also jointly generates multiple environmental, economic and socio-cultural outputs, some of which are being externalities or public goods, and for which markets may be either lacking or poorly functioning, hence farmers and landowners have very little appreciation, if any, of its aggregate economic value. For example, paddy fields have the ability to retain water for longer periods of time enabling them to perform extra functions on groundwater enrichment/replenishment, reduction of excessive run-off and river flooding. Biodiversity is an important aspect of paddy farming, where it plays hosts to varied plants and animal life (Concepcion et. al, 2003).

There are a number of different ways in which the various agricultural systems may be integrated or interact to assist the development of sustainable agriculture, each of them appropriate in different situations:

1. The continued application of traditional systems that function productively, sustainability and in a socially inclusive manner, and the reestablishment or replication of these systems.

2. The augmenting of indigenous knowledge within traditional systems with appropriate modern practices that can enhance the system, particularly modern organic practices such as composting, microbial inoculations, and appropriate scale mechanization. Another example is the addition of appropriate small-scale technology—such as gravity-fed technology for sprinkler and drip irrigation for vegetable and fruit cultivation—which could enhance their production and income-generating ability (ESCAP, 2002, p.43). According to the ESCAP report, Organic Agriculture and Rural Poverty in Asia, “organic framing could increase the yield of traditional and low-external input farming systems through its agro-ecological management practices by 200-300%”.

3. The application of traditional practices to modern agricultural settings, for example, much of modern organic agriculture has been developed outside of formal institutions by this approach.

4. The augmenting of modern agricultural systems with specific practices from traditional systems and organic, such as rotational, trap and intercropping, and agroforestry.

5. The emerging technology of genetic engineering may be able to contribute productive species, although there are issues relating to control of seed resources and unintentional gene transfer that may create some limitations here. Additionally genetically modified plants are not acceptable or organic systems.

There is no one ideal agronomic/forestry/aquaculture system. Rather the ideal may be context-dependent systems that combine elements of traditional, organic and modern practices in a locality and constraint-specific manner to maintain food security and improve micronutrient content of food with minimal adverse environmental consequences and maximum improvement in social inclusiveness. Traditional knowledge is assumed to reside locally within the farming community where it is applicable, and hence transfer of knowledge is more in the realm of farmer to farmer than from scientist and extension agent to farmer. A description and understanding of what makes various traditional systems stable would be valuable, enabling the utilization of this knowledge to develop more sustainable organic and modern systems for use by future farmers.

2.4 Impacts of AKST on Development and Sustainability Goals

2.4.1 Reducing hunger and poverty

Over the last three decades ESAP has managed such economic growth that it is the only region whose population has experienced a decline in rural poverty. It is safe to say that during that time, AKST, through the application of research from high yielding seed varieties, improved farm management and the containment of insect and pest depredations, has enabled farmers to substantially increase the region's agricultural productivity. The World Development Report shows that for East Asia and the Pacific food production index (with a base year of 1989-91) moved from 67.0 in 1979-81 to 152.1 in 1996-98. South Asia moved from 70.4 to 122.1 over the same period. In the case of S Asia the table shows that agricultural machinery, in the form of tractors per thousand agricultural workers, increased from 2 to 5 over a similar period (1979-81 and 1995-97). The figure remained the same, 2, for E. Asia and the Pacific region over the period (IBRD: Selected World Development Indictors, Environment, p289).

There is a large literature on the beneficial effects of irrigation on rural poverty alleviation. For example, Bhattarai et al. (2002) found that irrigation increases cropping intensity and thus crop revenue per hectare in Vietnam, India and Sri Lanka. The gross margins are between 20-110% in the irrigated agriculture over the rainfed systems. The study by Huang et al. (2006) showed that irrigation contributes to increases in yields for almost all crops and in income for farmers in all areas in China. The study by Lipton and Litchfield (2003) for some ESAP countries also showed similar results.

Improved irrigation access is a powerful instrument for reducing rural poverty in a given area. This is not only through the direct impact of increased yield and farm returns per se, but more through indirect impacts like increased rural employment and the feedback and multiplier effects associated with the provision of irrigation infrastructures. From a broader national perspective, Bhattarai et al. (2002) estimated a multiplier of 3.15 for irrigation in India, meaning that for every $1 generated by irrigated crop production that directly benefits farmers, another $2.15 indirectly benefits economic development. Poor communities, women in particular, also benefit from irrigation as a source of water for domestic uses, small-scale industry, and fishing (Meinzen-Dick and van der Hoek, 2001).

Lipton and Litchfield's study (2003) for some Asian countries suggested that the degree of the impact of irrigation on poverty reduction depends upon the structure of a rural economy and on how the additional farm income is actually spent within a rural economy, and its feedback impacts on rural employment and rural wage structures. The level of economic multipliers operating in a regional economy is crucial in determining the impact of irrigation on the poverty status and the inequalities in income distribution within that particular economy.

However, not all evidences have suggested significant impacts of irrigation on poverty alleviation. For example, Fan et al. (1999) showed that the marginal impact on poverty alleviation of irrigation in India ranked behind investments, such as rural roads, agricultural research and education. Rosegrant and Evenson (1992) found that irrigation did not have a significant impact on total factor productivity in India. The study by Lipton and Litchfield (2003) suggested that the underperformance of irrigation systems can aggravate the income gap and the relative poverty level within irrigation systems, leading to an unequal distribution of irrigation benefits across sub-systems. Therefore, additional direct public policy interventions and more pro-poor institutional and policy reforms are required to ensure the fair distribution of the benefits of irrigation.

[Insert Figure 2.21: Progress of yield improvement (1950 to 2005) in rice-wheat systems of Indo-Gangetic Plains and the sequence of contributing factors]

Science and technology have been responsible for an increase in agricultural production in Asia, but in some cases at a huge environmental and social price. Some of the undesirable effects of the technology include narrowing genetic diversity of food crops, intensive use of chemicals, loss of traditional knowledge and practices, loss of soil fertility and farmers dependency on external inputs that perpetuates indebtedness and intensive use of chemicals.

Some key questions that arise are: Has the economic benefit been uniformly distributed across the heterogeneous composition of the farming families? How has the narrow focus on increasing productivity impacted the social and ecological systems that determine the welfare and quality of life?

This subchapter of the chapter assesses how science and technology in agriculture have impacted the poverty levels of a large majority of people in Asia who are dependent on natural ecosystems. It also assesses the lessons learned from ecological agriculture, based on the principles of a forest ecosystem and practiced for thousands of years, and their relevance for the present challenges facing agriculture, science and technology.

Human well being has multiple constituents that include freedom and the ability to exert choice, good social relations and security (MA 2005). Poverty and malnutrition are multidimensional and are manifestations of pronounced deprivation of the well being constituents. The experience of poverty is contextual reflected by political, environmental, demographical or cultural factors. As stated in chapter 1, the MA also demonstrates the links between condition of ecosystems, the ecosystem services (provisioning - such as food, regulating -such as flood control, supporting – such as soil formation, and cultural) and human well being. Humans, while buffered against environmental immediacies by culture and technology, are ultimately dependent on the flow of ecosystem services which in turn are determined by the biodiversity (MA 2003).

While it is obvious that humans depend on earth's ecosystems, it is also necessary that human intervention should enhance human well being without having negative impacts on the ecosystem. The regulating, supporting and cultural services that ecosystems provide are essential to well being of people especially those living in rural areas and practicing traditional agriculture. In terms of provisional services, in addition to food, people also depend on such products as medicinal plants, fuelwood and non-timber forest products for their livelihood. (Davies, 1996; Chambers, 1977;Carney, 1998; Ellis,1998; Koziel, 1998; Scoones, 1998; Neffjes, 2000).

2.4.2 History of agrarian change and development

A background to Asia's history of agriculture, colonization of many countries, food production, export markets and domestic needs is necessary for an understanding of the advent of technological intervention that was thought imperative to tackle the food requirements of the region. The thrust to increase food production post World War Two spread across Asia's rice-growing belt and heralded the Green Revolution technologies. Modern plant breeding, improved agronomy and the advent of the inorganic fertilizers and modern pesticides further contributed to the advances in the new technology.

As an example, colonized Indian agriculture experienced increased agri-exports under the obligation to pay taxes, resulting in diversion of resources away from domestically consumed products, falling availability of food and increased vulnerability to famine. Some of the causes attributed to this include the adverse balance of trade through the process of commercialization of agriculture, the inability of India to pay for the rapidly rising imports of British manufactured goods other than the export of food grains (Bhatia, 1967). The grain trade concealed the fact that the homes and villages of a cultivating nation were denuded of their food to meet the annual demands of Britain (Dutt,– R.C 1901) .

Alongside there is also historical evidence from India and other Asian countries, such as the Philippines, that there was a vast crop diversity (species and varietal) that provided the quality and quantity of food that was needed. These contributed to various aspects of human well being and also acted as a safety net. The keys to solving agricultural problems in India could be found by making a careful study of eighteenth century Indian peasant technology. Examining historical inscriptions and survey reports during the British period there is evidence to show high yields (Table 2.18). In Malabar alone more than fifty kinds of rice were cultivated. Due to changing patterns of cultivation that followed increasing productivity has been considered a major problem. The problems of increasing food production should be seen in the historical background of abundant yields (Darampal, 2004).

[Insert Table 2.18: Historical estimates of agricultural yields in India]

Due to changing patterns of cultivation and commercialization of agriculture during the colonial period, there was a negative impact on the availability of food and therefore the need to increase productivity was considered a major priority.

Another example is Korea colonized by Japan where despite a reasonably high rate of growth of production, under pressure to export, the per capita cereals available for Koreans fell substantially to the extent that the poorest rural Koreans were reduced to eating wild grasses and tubers for a part of the year (Hayami and Ruttan, 1970; Cummings, 1981). Thus colonized countries experienced the transfer of resources via export of agricultural and mineral products required by the colonizing countries (Patnaik, 1996).

2.4.3 Effect of introduction of technology

Agricultural modernization has focused on wheat, rice and maize. To achieve higher yields for rice and wheat, one of the widely introduced technology was the development of crops that were more responsive to external inputs in the form of chemical fertilizers and crops that had shorter, stiffer straw to support more grain yield. These are termed High Yielding Varieties (HYV). However, the term High Yielding Varieties is a misnomer as it implies that the new seeds are high yielding in themselves. The distinguishing features of the seeds, however, are that they are highly responsive to certain key inputs such as fertilizers and irrigation. As early as 1970s, the term "High Responsive Varieties" instead of High Yielding Varieties was suggested (Palmer (1972). They can use larger quantities of nutrients and water efficiently than the earlier varieties, which tended to lodge or fall down if grown in soils with good fertility. They thus have a more favorable harvest index, i.e., the ratio of the economic yield to the total biological yield, (Shiva, 1993).

The adoption of High Yielding Varieties (HYV) – often termed the Green Revolution - occurred quickly. By 1970 about 20% of the wheat area and 30% of the rice area in the Asian region were devoted to the HYVs (CGIAR 1985). By 1990s the share increased to 70% for both crops and in India, wheat went up to 83% (Groosman et al.,1991). Almost all the area (around 94% wheat and 98% rice) under HYV cultivation in the world was in Asia, of which nearly half was in India (Pearce, 1980).Genetic modification for disease or pest resistance will not solve the problem as intensive agriculture itself creates the conditions for new pathogens. A variety of rice hybrid called IR-36 created to be resistant to eight major diseases and pests including the bacterial blight and tungro was nevertheless attacked by two new viruses called "ragged stunt" and wilted stunt. (Ho ,Mae Wan) Where there were 30,000 strains a few years ago, no more than a dozen dominated three-quarters of the land (Development Forum, 1989).

The introduction of HYV more than doubled cereal production in Asia between 1970 and 1995. It is claimed that overall rural non-farm economy was found to be stimulated, the overall poverty between 1970 and 1995 declined to less than one third and the absolute numbers fell from 1.15 billion to 0.825 billion (Hazell 2003). There was also the assumption that it resulted in a steady decline in poverty and better nutrition through increased income levels. This greater production came with a price on social and economic systems.

Agrarian studies in Asia and particularly in India on the effects of agricultural modernization vary widely in style and temper, (Mohanty, 1999), but they generally subscribe to three viewpoints:

- That modernization has further exacerbated the inequities instead of removing the earlier inequalities. (Parthasarathy 1970, 1991; Frankel and Franciner, 1971; Epstein and Scarlett, 1978; Gupta and Biplab, 1977; Pearse, 1980; Dhangere, 1987; Mencher and John, 1978 and Griffin, 1972).
- That by improving the economic conditions of the poor and the land less in agriculture the existing inequalities have been reduced. (Byln, 1983; Hazell and Peter, 1991, Ahluwalia, 1978; Lipton and Longhurst, 1989; Mellor, 1976; Shergil and Singh, 1995).
- That modernization of agriculture has had mixed effects (Bhalla and Chadha, 1983; Naidu and Chandrasekara, 1997 and Agarwal and Bina, 1983).

Some of the differences arise due to the different proxy indicators used to measure, economic analysis, welfare and food security. The choice of indicators and their use and interpretation is assessed below.

The economics of increased production of rice and wheat during the green revolution period puts a dollar value that overlooks: The loss in diversity and the equivalent monitory value when farmers from the diversity based systems to the monocultures; The extra costs of GR systems, not only in the form of chemical inputs but also in the resulting costs of environmental degradation? And who benefited from the surplus that was generated?

It is common to find literature using calorie consumption to define the poverty line which is a narrow approach (Chambers, 1988). Food security is ideally defined as physical and economic access to food at all times to ensure healthy and active life. However in practice food security is equated to absence of hunger or at best provision of a pre-determined number of calories at the household level. Thus food security becomes a reality at a household level on a day-to-day basis. Incidence of hunger defined as the absence of two meals a day is limited to a small number of people in isolated pockets and during certain parts of the year.

Food security has been described as the level and variability of satisfying nutritional requirements. It is emphasized that small changes in availability can create large changes in entitlement (Sen, 1981). Thus access to food – both quantity and quality/variability- is an essential component. This is a significant departure from the explanations of famine in terms of decline in food availability. This provides a rich insight into understanding food security since it includes not only legally enforceable entitlements but also market induced entitlements (Dreze, 1994).

For subsistence peasants food security depends on access to resources and production. For the landless and nett-buying marginal farmers it depends upon employment, high wages and low food prices. On the other hand for nett-selling farmers food security depends on favorable terms of trade and productivity for urban markets, on employment, low wages and low food prices and for urban marginals on food subsidies and income transfer (Dejanvry, 1981).

Food security and hunger has also been seen as a major livelihood issue. It has also been viewed in the larger context of international policies, sociological development, cultural needs, technological capability and sustainability by millions of farmers who have preserved the technology of growing food through low external input agriculture (Mukherjee, 2004).

Agriculture accounts for a significant part of the GDP throughout the region and has grown at a remarkable rate during the past thirty or so years. Nevertheless as a consequence of Green Revolution, the region has a greater number of malnourished and poor than any other developing region and more than two thirds of these reside in rural areas (Dixon et al, 2001).

The Green Revolution technology and package were intimately tied to the purchase of input seeds, chemical fertilizers, pesticides and intensive irrigation - all external inputs. Its impact includes the high level of dependency it created in the form of external inputs and debt levels of farm families. Alternative systems of knowledge were neglected and the approach led to conceive farmers as ignorant and devalued local and indigenous knowledge. (Gadgil, et. al., 1996)

Some of the core problems that have emerged are due to the limited or no consideration of the effect of the technologies, to a great loss of the linkages between the ecological basis of agriculture and the concept of food production. Homogenization of agricultural systems irrespective of the subsistence needs, ecology of the area, soil conditions and other environmental factors have opened a Pandora’s box, which are highlighted below.

2.4.4 High yielding (response) varieties and effect on biodiversity

Here the effect on biodiversity at genetic including varietal, species and ecosystem level is considered. Genetic resources are the only raw material in the world that are collected without compensation from the custodians of these resources. Over the last decade of intensified collection, more than 90% of the seed comes from the Third World, and almost the same percentage has either gone to the industrialized countries (where plant patent legislation prevails) or to the International Agricultural Research Centers (IARCs) located throughout Third World regions. These are outside of sovereign control and of the donating countries and especially the farmers who have cultivated these seeds for generations. It has also been argued that ex situ conservation in gene banks was sufficient to protect the genetic resources. However, recently there has been a realization that the genetic material in ex situ conservation suffered from the limitations of the cold storage system was capital intensive and not accessible by the farming community.

The changes in cultivation patterns from the multi cropping to mono cropping also contributed to the loss of genetic and varietal diversity in the agricultural systems. For example, in South India intercropped sorghum provided, apart from the sorghum, some 70kg of different pulses and 10kg of local oilseeds per acre. The loss of these varieties with the introduction of the new uniform sorghum varieties has reduced the availability of protein and fat sources at the local and household level. The millets that are nutritious and largely grown in semi arid tracts under drought conditions have by and large been lost either because they have been neglected or by passed.

In addition to these species/varietal level impacts, there are also effects on ecosystem functioning. The reduction of outputs of biomass for straw production was probably not considered a serious cost since chemical fertilizers were viewed as a total substitute for organic manure and mechanization was viewed as a substitute to animal power. However, the new dwarf varieties reduced the amount of straw available, changing the plant/animal/soil balance of local agricultural production systems.

The effect of HYV on the ecosystem functioning has not been well studied and thus as part of the Green Revolution, research on finding solutions has not necessarily focused on these. For example, a list of twenty four insect pests, sixteen diseases, eight soil problems, eight water and temperature problems and twelve other various problems were identified in a multiple country study (Hobbelink 1991). The study showed that 90% of all the main problems in rice growing had no effective solutions, while another four had been effectively addressed but only temporarily.

2.4.4.1 Loss of soil quality and changes in water use

Some of the consequences of the use of HYV and their reliance on external inputs have meant changing rainfed agriculture to irrigated agriculture and the reliance on ecosystem functioning for soil fertility and use of organic manure to use of chemical fertilizers. It has also meant extensive use of weedicides and pesticides destroying predators in addition to polluting the water and soils. Living and functioning soil is essential for supporting and functioning services, and thus for life support (Jayal, 1986). The complex processes of living soil are reversed with intensive chemical faming. While the contribution of pressures of human and animal populations on soil erosion and degradation has been commonly recognized, the contribution of inappropriate technologies to the destruction of soil has been overlooked. In India by 1990 about 60% of the cultivated area now has soil erosion, water logging and salinity problems. About 30 million hectares of fragile land now under cultivation is progressively degrading (Dudani & Carr-Harris, 1992).

The water resources crisis has escalated in the last fifty or so years. This crisis is ignored partly because it arises from invisible processes of destruction or destabilization of soil water and vegetation systems and partly because it affects overwhelmingly the poor who are directly dependant on these resources for their livelihood and survival. The destruction of the life support systems of the poor is the real cause of growing poverty and deprivation.

Seventy percent of Indian cropland is rainfed. These croplands play a fundamental role in producing staple crops: grains, fodder, oilseeds and pulses. Traditional rain-fed farming practices have evolved strategies to cope with the threat of drought. The central mechanism for conservation of soil moisture in rain-fed food systems has been the addition of organic matter to the soil to increase water-holding capacity. Genetic diversity in cropping systems has been a second insurance against drought. (Dixon et. al., 2001)'s analysis provides insight into the potential for reducing both hunger and poverty by improvement of smallholder farming systems.

The claim of the Green Revolution is that it is scale-neutral because of more harvests annually, higher yields and more work for laborers leading to higher wages with attendant improvements in living conditions. However, the real wages during the years 1970-71 to 73-74 in Uttar Pradesh when the Green Revolution was making a big impact on yields showed that wages decreased by eighteen percent in this period because large landowners brought in more machinery and migrants to compete with local labor and the landless. Together with this the bigger farmers had access to subsidies for irrigation and credit from the government (Dogra, 1990). It is also observed that in most parts the green revolution has failed to raise incomes of the rural poor appreciably and contribute substantially to their effective purchasing power. (ILO 1977)

2.4.4.2. Use of HYVs, associated external inputs and the effect on the people's diets

Effects on diets come from HYVs leading to decreased integrated farming practices. Losses in diets are due to loss of resource base, such as fish, snails, frogs and birds from the paddy fields, which are an additional source of food for the farmers. Another dietary loss is the "weeds" and wild plants that exist along with the crops, some used for food, while others used as raw materials, sometimes by women in the production of items to be sold for additional income. Pesticides also impact the health of the buffaloes and then affect human health and livelihood.

2.4.5 Increase in pesticide fatalities

The chemicals that cause soil degradation also have had a direct bearing on the quality of life of the farmers. Though developing countries use less than one quarter of the world's pesticides they suffer three quarters of all pesticide fatalities - 375,000 people in the Third World are poisoned and 10,000 killed by pesticides each year (Bull, 1982)). These figures do not include chronic or long-term results such as cancer, birth defects, sterility or suicide poisonings. Pesticide use is expanding more rapidly in the Third World than elsewhere, e.g., pesticide imports quadrupled in the Philippines between 1972 and 1978. Meanwhile there are stricter controls over pesticides in the industrialized world. In 1979, twenty five percent of pesticides exported to the Third World by the USA were banned or unregistered in that country. Similarly total chemical nutrients used in India's agriculture increased from 178,000 tones in 1965-66 to 4,497,000 tones in 1978–79 (Alvares, 1986). The warnings and instructions for use, if the manufacturer provides them at all, are often difficult to understand, as many farmers can neither read the directions nor follow the diagrams. Advertisements for pesticides may not provide complete information and it is common for farmers to buy a product and only then discover all of the requisite safety equipment and precautions, much of which may not be available, or suitable for the specific conditions (Caulfield, 1984).

Some of the pesticides that were used are the so called "persistent organic pollutants (POPs) and despite being present in very small quantity in water and soil bio accumulate in humans and thus have an adverse impact on health and reproduction. In addition, pests have acquired resistant to them, escalating their use causing damage to human health, animal health and ecosystems (Joshi, 2005; Nair, 2000).

2.4.6 Cost and Debt

The Green Revolution model cannot be sustained without massive subsidies. The subsidy in India on nitrogenous fertilizers by 1990 alone had reached 200m rupees (approx US$40mand was expected to rise to 500m rupees). On the consumption side, around 80m rupees is required so that the prices of commodities like wheat and rice remain low. But even with these subsidies, the farmers do not make a profit. A study done in 1981 in the Philippines showed that although the farmers were producing 72% more, they were earning 38% less due to the increase in money necessary to purchase inputs and the depressed prices of rice.

These conditions have locked farmers permanently into the credit/debt cycle. Because of this indebtedness, farmers are required to bring their grain to the market in order to repay loans, instead of using it to feed themselves. This has had a negative impact on nutritional levels, particularly due to the decline in pulses (Alvares,C 1986).

Now that the problems of chemical pollution and pesticide residue in food are highlighted, biotechnology and genetic engineering are proposed as solutions. It is also argued that molecular biology research has matured to the stage where its techniques and procedures can produce products of commercial relevance. The acceptance of these techniques depends upon many factors beyond the realm of science itself. Despite perceived advantages like enhancing production, possibilities of improving quality, serious reservations persist about health and environment implications of large-scale application of biotechnology. It should also be discerned that given the diversity of natural and social environments in South Asia it is prima facie not to be expected that the new technology would operate in the same way or have the same social and economic effects all over South Asia (Farmer 1986). Studies involving analysis of the collective impact of modern technology on social indicators such as poverty levels and food security both at the micro and macro level are almost non-existent. This brings us to understanding the question of development not as economics or sociology or technology alone but that which should be backed by revolutionary reforms. While the application of science and technology are desirable for agricultural growth but inadequate to remove social inequalities.

Technical acceptance is based on governance by a balance sheet of risks and benefits. The need for a quantum increase in agricultural production through increase in agricultural productivity at the same time as conserving natural resources and not damaging the environment and ecology is urgent. At the same time technological intervention will have to ensure that the food security and livelihood of the vast farming community is not threatened by a monopolistic control (Singh, 2002).

Data clearly indicates that HYV technology is inefficient in energy usage; compared to traditional technologies; the difference in the energy efficiency of the old and new technologies can be as large as 50-250 times. Diminishing returns of land productivity because of the introduction of pesticides and chemical fertilizers create a need for more and more inputs to reap the same yield. The new technology is capital intensive. It commits the nation to large investments from predominantly foreign corporations. In nitrogenous fertilizer alone Indian indigenous capacity had to be increased from 0.37mT of nutrients in 1967-68 to 2.23mT in 1979-80 (worth 60billlion rupees in 1980 prices). Furthermore, production capacity had to be generated for tractors, diesel-sets, etc., and every farmer adopting this new technology had to invest their own capital to acquire these machines, which often came from public financing agencies (The Organic Farming Source Book, 1996)

According to Rossett and Collins (1998) what made possible greater hunger was the failure to address unequal access to food and food-producing resources. While rich farmers can, poor farmers' cannot, afford to buy fertilizers and other inputs in volume, hold out for the best price for their crops, pay for irrigation, and access government-subsidized credit, all mechanisms to access the technology package. Further narrowly focusing on increasing production, as the GR does, cannot alleviate hunger because it fails to alter the tightly concentrated distribution of economic power, especially access to land and purchasing power. According to(Rossett P 1998) The Green Revolution myth goes like this: "the miracle seeds of the Green Revolution increase grain yields and therefore are a key to ending world hunger. Higher yields mean more income for poor farmers, helping them to climb out of poverty, and more food means less hunger. Dealing with the root causes of poverty that contribute to hunger takes a very long time and people are starving now. So we must do what we can-increase production. The Green Revolution buys the time Third World countries desperately need to deal with the underlying social causes of poverty and to cut birth rates. In any case, outsiders-like the scientists and policy advisers behind the Green Revolution-can't tell a poor country to reform its economic and political system, but they can contribute invaluable expertise in food production. While the first Green Revolution may have missed poorer areas with more marginal lands, we can learn valuable lessons from that experience to help launch a second Green Revolution to defeat hunger once and for all"

The argument is further substantiated in their report with facts and figures from the south Asian region. In south Asia, there was 9 percent more food per person by 1990, but there were also 9 percent more hungry people. It was not increased population that made for more hungry people. The total food available per person actually increased. What made possible greater hunger was the failure to address unequal access to food and food-producing resources.Similarly in central Luzon, Philippines, rice yield increased 13% during the 1980s, but came at the cost of a 21% increase in fertilizer use. In the Central Plains, yields went up only 6.5%, while fertilizer use rose 24% and pesticides jumped by 53%. In West Java, a 23% yield increase was virtually cancelled by 65 and 69% increases in fertilizers and pesticides respectively. Obviously an unsustainable model of increasing food production.

2.4.7 Impact on farmer's rights

India is among the first countries in the world to have passed the legislation granting Farmer's Rights in the form of protection of Plant Varieties and Framer's Right Act 2001. In the recent years an alarming trend in suicides have been witnessed. But for the media reports there are no official reports that are available. One of the most common methods of committing suicides appears to be consumption of pesticides. The exact reason has been a matter of debate. There are studies that have asserted debt as a major cause. This apart crop failures due to over use of pesticides and the supply of spurious seeds are some of the causes for suicides. The truth of the matter is that suicide rates are on the increase. In the same report by Ramanna (2006) interviews with CSOs express the view that farmer's rights is just not an alternative to breeder's rights. On the other hand it should be multidimensional including rights to conservation of biodiversity, inputs affordable to the farmers equity and justice and above all right to quality reliable seeds. In other words the value of conservation of indigenous diversity has been implied.

In Asia Pacific region alone it is observed that rain fed agriculture supports 1.5 billion people covering an area of 223 million hectares. The problems faced by the rain fed agriculture sector are mainly caused by lack of policy support, resources and research interventions. Despite the great thrust on irrigated monocultures the diversity and complexities of the rain fed systems remain intact. Diversity in rainfed areas in not only within species but it exists also among species. The role of farmers and decentralized research has the potential to increase the production that is based on biodiversity and the key to solving the food needs of the people dependant on rainfed agriculture lies in using the diversity. (The SEARICE Review1996)

2.4.8 Comparing the green revolution and biorevolution

Biotechnology is often heralded as the tool to correct the problems and shortcomings of Green Revolution. Comparing the GR and 'bio revolution' reveals the much deeper impacts and wide-spread implications of the latter technology through these categories: crops and other sectors affected, territories affected, development of technology and dissemination, proprietary considerations, capital costs, access, research skills required, crop vulnerability, and side-effects (Hobbelink, 1991). The new set of technologies – being developed mostly by the industrial nations - opens up huge possibilities to penetrate much deeper into the molecular structure of the plant and its genetic components. Table 1 shows the variety of crops affected by the Green and bio-revolution, their scale of implementation, the technology and research needs and the effects on the society.

[Insert Table 2.19: Comparing the Green Revolution and the Bio Revolution]

2.4.9 Can genetic engineering alleviate hunger?

Both supporters and opponents of transgenics have their argument on concerns for the poor. Proponents address food security in macro terms. The impact on poverty needs to be assessed beyond production and agriculture. Some, not all, poor are farmers. Nor does greater aggregate production necessarily benefit the poor. Yet the claims made by the proponents emphasise the fact that GMOs will help alleviating problems of hunger in the world. How do they plan to feed the world? Nothing could be simpler according to Robert Horsch, Director of Technology at Monsanto who espoused the virtues of GMOs in a speech delivered at the end of 1997 in Austria Perriere and Frank(2001).

"The key contribution of Biotechnology will be several fold producing more food on the same area of land, thereby reducing pressure to expand to wilderness, rainforests or marginal lands which support bio diversity and vital ecosystem services reducing post harvest loss of food caused by disease, pests and decay and improving the quality of fresh and processed foods thus boosting the realized nutrition per acre, displacing resource and energy –intensive inputs such as fuel, fertilizers or pesticide thus reducing unintended impacts on environment and freeing those resources to be used for other purposes or to be conserved for the future; encouraging reduction of environmentally damaging agricultural practices such as conservation tillage, precision agriculture and integrated crop management; stimulation of a new kind of economic growth; more benefits with less input and harm" .

Apart from the fact that research on development of GMOs is more adopted to the needs of the developed countries, now there is an attempt to serve the needs of developing countries by developing salinity and drought resistant varieties rather than herbicide resistance.

In an appeal made by Greenpeace, the Confederation Paysanne, Solagral, Veterinaires Sans Frontieres and several international solidarity and environmental protection associations condemned the presentation of GMOs as the solution to the problem of world hunger in 1998. They express the concern that the Green Revolution experience has taught us that no technical revolution can lead us to victory over malnutrition. On the contrary, the complexity of the techniques developed, their highly technical nature and high costs can only further marginalize the world's small farmers. The ecological impact of these monocultures, based on fertilizers, pesticides, irrigation and mechanization, is considerable and constitutes a threat to food security. Transgenic crops are developed on the same basis of the Green Revolution's high-yielding varieties and may further worsen the food security problem due to an even greater degree of technicality, an increase in the quantity of herbicides used and a greater concentration of seed and chemical suppliers.

[Insert Table 2.20: Arguments for and against the potential benefits of genetic Engineering]

Fields growing the engineered crop can be sprayed with the specific herbicide at any stage in the growing season to kill off weeds without killing the crop plants (Steinbrecher 1996). If spraying occurs regularly, there is every reason to believe that weeds in or near fields of genetically engineered crops would develop resistance to the herbicide the crop is tolerant of. As weeds become resistant, higher and higher doses of herbicide would need to be used, leaving larger and larger amounts of chemical residue on the crops. In addition, the engineered crop may itself become a weed. Alongside the development of herbicide tolerance and pest resistance, some scientists are seeking to engineer plants to be resistant to pathogens such as fungi, bacteria and viruses. The immediate hazard from herbicide – resistant crops is the spread of trans genes to wild relatives by cross hybridization creating super weeds. Ho, Mae Wan (1998)

In the case of pest resistance such as the dominant Bt, if insects developed resistance to the engineered Bt toxin, conventional farmers would have to go back to chemical insecticides, while organic farmers would have lost one of their most valuable pest-control agents. In addition super bugs could emerge – insects which have adapted their behavior and genetics in unpredictable ways to survive in the constant presence of toxins.

When it becomes evident that an engineered gene has delayed, or previously unnoticed, side effects or leads to unwanted and unpredicted plant behavior, farmers could stop growing the engineered crop so that no more direct gene transfer occurred. Such effects could include the triggering of allergies, or the weakening of a plant's defenses, resulting in the increased crop infections caused by pathogens. There is no way, however, to track down and recall to the laboratory all those transgenes already transferred into the wider environment. A ripple effect on other species- insects, soil organisms, birds, fish and mammals – will take place, even though it cannot be predicted when it will occur, to what extent or in which species. (Ricarda A. Steinbrecher 1996) In an interview with nine scientists about the risk from genetically manipulated plants (GreenPeace, 2005) with nine scientists , it was concluded that thee is new information emerging from the studies of epi genetics . It showed that gene sequencing alone does not determine how a gene or organism functions. The architecture of the DNA and how it is influenced by the environment also influences when and where a gene functions. This they say introduces a complexity that means there is insufficient knowledge to predict confidently how a genetically engineered organism will behave in all environments. It is also emphasized that the official risk assessments of Genetically engineered plants have failed to take this dimension of genetics into account.

In a most recent study Allison K. Wilson et al (2006) discuss the transformation induced mutations in transgenic plants and the implications for bio safety. The scientists conclude that the presence of transformation induced mutation in commercial crops poses a potentially large bio safety risk. This is again reiterated by invivo studies on possible health consequences of genetically Modified Food and Feed .The study calls for a transparent manner each individual product is tested before introduction into the market. Pryme,Ian F and Rolf Lembcke (2003)

[Insert Table 2.21: Benefits and concerns of transgenic crops]

2.4.10 What is sustainable in agriculture?

Sustainability in agriculture has been defined as having two dimensions, viz., natural resource sustainability and socio-economic sustainability. Natural resource sustainability is based on the stability of the ecology of agricultural ecosystems based on interactions between soil, water and biodiversity. This sustainability measures the wealth as “nature’s economy”. Nature’s economy includes biodiversity, soil fertility, soil and water conservation that provides the ecological capital for agriculture. Socio-economic sustainability refers to the social ecology of agriculture including the relationship of the society to the environment, the relationship between different social groups and stakeholders engaged in agricultural production. A recent study reported in the Scientific American has shown that economic calculations of agricultural productivity of the dominant paradigm distort the real measure of productivity by leaving out the benefits of internal inputs derived from bio diversity and not considering the externalities created by additional financial costs incurred by purchase of external inputs required for monoculture. (Bray,1994)

2.4.10.1. Sustainable agriculture: farmers and biotech approaches

There is a wide difference between the approach of the original farmers who were scientists in their own right and that of the new bio technologists. The first takes a broad and holistic approach to a specific agronomic and socio-economic situation; the latter tends to look for universal solutions deep down at the molecular level. Table 2 makes the comparison between farmers’ and biotech approaches. They offer widely differing solutions for problems such as: pests and diseases, weeds, water, plant nutrients, soil degradation and yield.

2.4.11 Agriculture and sustainability: the ecosystem approach

There is no reason why soils cannot be restored to fertility and productivity through ecological farming and forestry which builds on nature’s processes instead of destroying them. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way (Hage et al. 2002). An ecosystem approach is based on the application of appropriate scientific methodologies focused on levels of biological organisation and that encompass the essential structure, processes, functions and interactions among organisms and their environment.

The ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems. Ecosystem processes are often non-linear and the outcome of such processes often shows timelag.

The idea of agricultural sustainability centers on the need to develop technology and practices that do not have adverse effects on environmental goods and services and at the same time lead to improvements in food and productivity. Sustainable agriculture approaches may come under many names: agro-ecology, organic farming, low external input farming, ecological agriculture, bio dynamic agriculture and permaculture (Ho and Ching, 2003).

Increase in Long-Term Productivity with sustainable agricultural approaches. Pretty and Hine (2001) give an account of their study and observations on 286 interventions in fifty-seven poor countries covering three percent of the cultivated area in developing countries. Their observations reinforce the fact that there increased productivity while improving the supply of environmental and ecosystem services. There was an average crop yield increase of seventy-nine percent. All crops showed water use efficiency gains with highest improvement in rain fed crops. A similar study done by Pingali and Rosegrant (1994) shows that current rice yields on the irrigated lowlands of Asia dropped by five percent on total rice production and the impact on total rice production would be about 10 million tones per year based on the production figures for the year 1989-91. They explain that the problem of sustaining productivity growth comes about because of inadequate attention to understanding and responding to the physical, biological and ecological consequences of agricultural intensification. They emphasize the fact that the focus of research when shifted from a fixation on yield improvements to a wholistic approach toward the long-term management of the agricultural resource base has immense benefits. There are also experiments that show the low cost biological approaches can be an attractive choice when the application results in yield levels at par with conventional agriculture (Rupela, et al., 2004, 2005).

Evidence from hundreds of grass roots development projects shows that increasing agricultural productivity with agro-ecological practices not only increases food supplies, but also increases incomes, thus reducing poverty, increasing access to food, reducing malnutrition and improving livelihoods of the poor (Uphoff and Alteiri, 1999).

Agro-ecological systems lead to more stable levels of total production per unit area than high input systems They give more economically favorable rates of return, provide a return to labor and other inputs for a livelihood acceptable to small farmers and their families. They also ensure soil protection and conservation of agro biodiversity (Pretty, 1995).

Organic agriculture has the possibility of improving incomes, profitability and return on labor by removing or reducing the need for purchased inputs. Diversification, optimization of productivity and access to premium markets are some of the obvious advantages of moving from the conventional to the organic (Rundgren, 2002). Despite the innumerable studies and observations on the benefits of eco agriculture there is the threat of Genetic engineering and Genetically modified seeds promoted to justify the need to increase food production.

In the ESAP region agricultural development is an important component of development and poverty reduction programs for the foreseeable future. Some major resource degradation challenges as a result of past practices, as well as linkages to the off-farm rural economy, will need to be addressed.

Improved water resource management
Strengthening resource user groups
Re-orienting agricultural services
Improving rural infrastructure

The East Asia and Pacific region is the most populous of the six developing regions. Despite strong economic growth accompanied by a steady reduction in poverty in some countries, considerable hunger and poverty persist. The foregoing analysis has shown that rural development in the region should concentrate on the basic determinants of economic performance, particularly farm and off-farm rural economic growth. While many policies that emphasize social issues are extremely important, the resolution of these issues in rural areas depends critically on agricultural growth. Strong agricultural and off-farm economic growth, as well as improved household food security, are dependent on a set of enabling factors that create commercial farming systems where surpluses of agricultural products are produced for sale without compromising on the subsistence needs.

It should also be discerned that given the diversity of natural and social environments in South Asia it is prima facie not to be expected that the new technology would operate in the same way or have the same social and economic effects all over South Asia (Farmer 1986). Studies involving analysis of the collective impact of modern technology on social indicators such as poverty levels and food security both at the micro and macro level are almost non-existent. This brings us to understanding the question of development not as economics or sociology or technology alone but that which should be backed by revolutionary reforms. While the application of science and technology are desirable for agricultural growth but inadequate to remove social inequalities. (Pretty and Hine, 2001)

Sustainable agriculture clearly does not yet have all the solutions, but has the potential to address some of the key lacunae of the Green Revolution and other technology dependent programmes. With further explicit policy and institutional support, particularly through national policy reforms, these benefits to food security and attendant improvements to natural, social and human capital could spread to much larger numbers of farmers and rural people in the next decade.

2.4.12 Improving rural livelihoods

2.4.13 Improving nutrition and human health

In spite of the remarkable growth in agricultural production within ESAP during the last four decades, hundreds of millions of people still are living in hunger and poverty. The proportion of the population in developing countries underfed - consuming dietary energy inadequate to sustain more than light activity on average - was estimated to have fallen substantially over the last 15 years, from around one in three people in 1975, to one in five in 1989. This implies a considerable reduction in the numbers so affected, from nearly 1,000 million to just below 800 million. These calculations from FAO use a new indicator of low consumption, and revised methods of estimation, now including China. By this calculation, less people today are underfed than at any time in the recent past. This estimate is considerably influenced by the improving situation in China. Excluding China (and certain other East Asian countries, such as Korea and Vietnam), a slight increase in total numbers underfed is still estimated by FAO, from around 540 million in 1979/81 to about 580 million in 1988/90 (Garcia and Mason, 1992). South Asia is estimated to be improving slowly, according to recent results from India and elsewhere, at around a reduction of half a percentage point prevalence of underweight children per year. Nonetheless, the underweight prevalence in South Asia remains the highest in the world, and over half the world's underweight children are in this region. Indications are that calorie consumption remained low throughout the 1980s, with little change, although this may have improved slightly for some poorer groups such as the landless. Nutrition in South East Asia is improving rapidly in many countries, at around one percentage point of underweight prevalence reduction per year; this is in line both with considerable economic development, and with vigorous and widespread health and nutrition programs at village level. Food consumption is relatively good, and has risen during the 1980s, along with marked success in food production to the point that a number of countries changed from net food importing to exporting (Garcia and Mason, 1992). Iron deficiency, one result of which is anemia, is the only nutrition problem showing a general deterioration in many parts of the world. Prevalence is especially high in South Asia, where more than 60% of women are anemic. In general, trends in dietary iron supply are downwards, for example in South Asia due to reduced production of legumes with the green revolution, in line with the worsening of anemia (Garcia and Mason, 1992). Deficiency of vitamin A affects at least 40 countries, and, out of an estimated 14 million with resulting eye damage, blinds up to half a million preschool children each year. Important recent research shows that improving vitamin A status in children in deficient populations reduces mortality among young children by around one quarter. Vitamin A supply in some parts of South Asia is so low that deficiency is almost inevitable. The extent of stunting, underweight, and wasting in women in developing countries was assessed for the first time. The results show that these problems are very extensive in developing countries, particularly low body weight and thinness in Asia. Malnutrition in women is generally in line with estimates of low birth weight, and the intergenerational effects, of malnourished women having small babies who grow up to be small mothers, can readily be seen. Indications are that anaemia prevalences, already high, may be rising in South Asia (Garcia and Mason, 1992). Poverty is clearly a major determinant of nutritional outcome, and rapid economic growth has been a major solution to malnutrition for example in Southeast Asia. However, comparison of China with India shows (for example) that the former has a far lower level of malnutrition although a similar average income (although allowing for prices puts China considerably ahead); within India, the relatively low level of malnutrition in Kerala, nonetheless one of the poorer states, is parallel. The percentages of underweight pre-school children were 58.5 in South Asia, 31.3 in South East Asia and 21.8 in China in the year of 1990. The Numbers underweight pre-school children were 101.2 millions in South Asia, 19.9 millions in South East Asia and 23.6 millions in China in the year of 1990 (Martorel, no year). Technology and access to technology and innovations is not benefiting a large numbers of poor people in the South Asia. The question is 'Why?' Why are the benefits of technologies that are available in the countries of the South Asian region unavailable to all of the people in the region? It appears that technology development is geared through market pressures and needs of the developed world and not of the needs of the poor countries that have little purchasing power (Hidellage, 2003).

2.4.14 Environmental Sustainability

The state of conservation and management of natural resources within ESAP as a function of AKST was reviewed. The environment and natural resources reviewed include resource use (land and soil, water, biodiversity, energy use and efficiency, forests) and ecosystem services, waste management, resource conservation, conflicts in use, and response to natural disasters.

Agricultural operations, cropping, and natural resource extraction in forestry and fisheries has profoundly intensified during the past 50 years under review. In all areas of ESAP, many more areas were cleared to pave the way to agriculture. As a result of both intensification and extensification, food production has come up at pace with population increase. But trade-offs had been inevitable in the quest for more food production and economic development. The increase in food production through modern agriculture often has masked significant externalities, and sustainability is often ignored. Sustainability of agriculture depend greatly on conservation of natural resources and environment.

Sustainability of production systems declined due to deterioration of soil resources in terms of fertility and physical quality. Soil physical, chemical, and biological degradation was aggravated during the past 50 years. Soil erosion had been a perennial problem especially in sloping and unstable agricultural lands. In most intensive agricultural systems natural soil fertility had declined as a result of crop nutrient removal, nutrient leaching, chemical deficiencies and imbalances, and acidification. Organic matter and biological systems were adversely affected due to continuous cropping without consideration of soil regeneration capacity. In worst case, desertification had been encroaching, especially in the arid and semi-arid areas. Sound soil resource management technologies like crop rotation, green manuring, among others, were not mainstreamed because the dominant productions systems were focused on short term productivity.

Sustainability of Soil Resources

Soil fertility has been declining through the years in the form of: degradation of soil physical properties, adverse changes in soil nutrient resources, including reduction in availability of the major nutrients, micronutrient deficiencies, nutrient imbalances, and acidification through incorrect fertilizer use, depletion of soil organic matter, as well as decline in soil biological activity. Depletion of soil primary minerals and organic matters occur in the form of micronutrient deficiency, like iron, manganese, zinc, copper, boron, nickel, molybdenum, etc. Heavy crop demand over time intensifies the severity of the deficiency, and exhausts the soil's ability to supply sufficient quantities of other micronutrient elements.

Physical soil degradation. Soil physical degradation is related to decline in soil structure leading to accelerated erosion, compaction, crust formation, and excessive overland flow. South Asia (India, Bangladesh, Nepal, Sri Lanka, Bhutan) has 140 million hectares, or 43 percent of the total agricultural area of the region suffering from several forms of soil quality degradation. (FAO, UNDP, UNEP 1994). Soil erosion is the most pervasive problem. Erosion removes the soil organic matter where much of the soil's nutrient reserve exists and consequently causes nitrogen loss and other nutrients. In China, about one third of its land area, amounting to 367 Mha, faces erosion problems. While 25 percent of the total agricultural land of India is affected by soil degradation with 2.7Mha of land east of Bihar suffers from soil erosion mainly from shifting cultivation.

According to Oldeman (1994) the most severe water erosion occurs in the Himalayas, Central Asia, China, the South Pacific and Australia, while wind erosion is worst in South Asian sub-region India. Sediment yields are reported to be high from Indonesia, Malaysia, Papua New Guinea, Australia, Philippines, and Thailand (Jansson, 1988). Also, severe water erosion is extensive in southeast Asia, including Burma, Thailand, Malaysia, Indonesia, and the Pacific and Oceania (GEO3 Report).

Chemical soil degradation. Depletion of plant nutrients (N. P, K, Zn, S) is the most common form of chemical degradation of the soil. Nutrient loss is widespread and substantial in the ESAP region due to intensive cropping and relying mostly on chemical fertilizers composed of at most only three of the 32 nutrients needed for plant growth. Increasing nutrient imbalances leading to micronutrient deficiency or toxicity of trace elements are very common in continuously irrigated paddy fields.

Acidification is also a form of chemical soil degradation and it is caused by the depletion of cations (Ca, Mg, K) and the accumulation of H and Al on the exchange complex. Soil pH is evolving towards greater acidity which ultimately affect soil nutrient availability. Many parts of Bangladesh and northern India have acidified and salinized, with a consequent losing of nutrients. Also, many agricultural land in Cambodia, Malaysia, Thailand and Vietnam has been degraded by acid sulphates (Oldeman 1994). In Australia, Bangladesh, Nepal, and Sri Lanka, poor soil nutrient balances are not uncommon. As a result, test plots in IRRI revealed that varieties yielding 10 tons per hectare in 1966 only produced 7 tons per hectare in the mid-1990s.

Soil salinization is becoming another problem despite modern agricultural technology. Saline soil is defined as soil with electrical conductivity in the saturation extract (ECe) exceeding 4 mmho cm-1 (4 dSm-1) at 25°C. pH below 8.5 and ESP (exchangeable sodium percentage) less than 15. Salt injury depends on species, variety, growth stages, environmental factors, and nature of the salts.

About 320 million hectares of land in South and South East Asia has problem of soil salinity. Salination has reduced crop yields on 7 Mha in China; while at least 2Mha in India have been abandoned due to salinization (WRI, 1996). Similarly, more than 8 percent of irrigated area in Australia, in addition to 4.5Mha of drylands (10% of all croplands), are affected by salinization.

Desertification is also encroaching and most prone are the arid and semi-arid areas of the region. This is aggravated by improper farming techniques, intensive farming, and too much animals foraging per unit area. “Of the 1,977 million ha of drylands in Asia, more than one-half are affected by desertification. The worst affected area is Central Asia (more than 60 per cent) followed by South Asia (more than 50 per cent) and Northeast Asia (about 30 per cent)” (UNCCD

1998). The Gobi Desert situated in the northern and western parts of China is reported to have expanded by 52,400 sq. km over a period on five years.

Biological degradation. Soil biota are very important components in soil fertility and health, thus sustainability, because they facilitate nutrient cycling and help improve soil structure. The decline is mostly due to intensive chemical inputs which not only alter the chemical properties of the soil, but decline in organic matter and humus acting as food for the microorganisms.
Some agricultural technologies had been developed, such as nitrogen-fixing bacteria and mycorrhyzhae, for efficient and sustainable nutrient cycling. Mainstreaming of these more sustainable technologies, perhaps are hindered by the dominant paradigm of quick results syndrome.

Water depletion and degradation. Increasing water withdrawal for irrigation has led to serious environmental consequences, particularly water resources depletion and ecosystem degradation. Overall, the ESAP region is relatively well endowed with water resources. For a total area representing 21 percent of the world's land surface, it has 28 percent of its water resources (blue water). However, as the region is home to 53 percent of the world's population, the amount of water resources per inhabitant is only slightly above half the world's average.

The hydrology of the ESAP region is dominated by the monsoon climate which induces large inter-seasonal variations in rainfall and river flows. In this situation, average annual values of river flows are a poor indicator of the amount of water resources available for use. In the absence of flow regulation, most of the water flows during a short season when it is usually less needed. In Bangladesh, for example, the surface flow of the driest month represents only 18 percent of the annual average; in Indonesia, it is 17 percent. In India, the flow distribution of selected rivers in the monsoon period represents 75-95 percent of the total annual flow. In north China, about 70-80 percent of the annual rainfall and runoff is concentrated in the period between May and September (FAO, AQUASTAT, 2006). This means that irrigation is important for the crops produced in other months of the year. For example, winter wheat which accounts for over 90% of total wheat sown areas and production in China is grown between October and June next year. There is little rainfall during this period. The production is heavily reliant on irrigation, which is the largest water user in the water stressed North China Plain (Yang and Zehnder, 2001).

In many rivers in the region, annual discharges have been declining due to the increasing water withdrawal. Some rivers are completely tapped out during the drier part of the year. The Yellow River, the cradle of China's civilization, stopped flowing in its lower reaches for several months every year during the 1990s. The longest dry up period occurred in 1997, a record 226 days

(Postel, 1999). Consequences of reduced river flows and river dry ups are rather serious. The capacity of the river to carry sediment load is reduced, potentially increasing the risk of floods in the lower reach. The dry ups also have adverse impacts on the aquatic, wetland and estuary ecosystems of the downstream areas, in particular, the coastal fisheries.

Over extraction of groundwater and consequently groundwater depletion have been widespread problems, especially in the semi-arid areas. In the North China Plain, the groundwater table has been declining on a rate of over 1 meter each year. In Punjab state in India, the situation is similar. The rapid decline in groundwater tables has reduced the resources availability on the one hand and increased the cost of accessing the resources on the other. Poorer farmers are hit the most. When near the sea, or in proximity to saline groundwater, over-pumped aquifers are prone to saline intrusion.

Water quality is also threatened by the intensive application of fertilizers, herbicides and pesticides that percolate into aquifers. These non-point sources of pollution from agricultural activity often take time to become apparent, but their effects can be long-lasting, particularly in the case of persistent organic pollutants. Wetlands are also affected by over extraction of river water and by dropping groundwater tables.

Water scarcity has become a major concern in many countries in the region. Increased competition for water between sectors already affects agriculture in China, India, Malaysia, Thailand and the Republic of Korea and the trend is towards an intensification of the problem due mainly to the population growth and the rapid expansion of the domestic and industrial sectors in these countries. Major inter-basin transfer programs are reported in many countries, notably China, India and Thailand.

In arid and semi-arid areas, waterlogging, salinity and alkalinization are considered serious constraints on agricultural development in irrigated land. The principal effect of salinity is to reduce the availability of water to the plant by high osmotic concentration of salts in the soil solution. Saline/alkaline cultivated land in China covers about 7 million hectares. In India, waterlogging due to irrigation covers an area of about 2.46 million hectares; 3.06 million hectares are affected by salinity and 0.24 million hectares by alkalinity problems. Salinization is also a serious problem in the Murry-Darling basin in Australia and a number of other countries in the region.

Data for actual areas damaged by salination are sporadic and vary largely amongst different sources. Table 2 provides the data for some of the ESAP countries compiled from different sources.

[Insert Table 2.22: Irrigated land damaged by salination in selected ESAP countries]

Declining yield. The trends of crop yield of many long term experiments (LTEs) have shown declining rice and wheat yields (Cassman et al., 1995; Nambiar, 1994; Brar et al., 1998; Yadav et al., 1998, 2000; Duxbury et al., 2000). Over a cropping period of 20 years, Regmi et al. (2002) reported wheat yield decline at 0.05 Mg ha-1 yr-1 (with both NPK and Farm yard manure). In another experiment, rice yield also declined by 0.02 to 0.13 Mg ha–1 yr–1 (Yadvinder-Singh et al., 2004). There are exceptions, though, where yields either increased or were maintained (Aggarwal et al., 2000a; Yadav et al., 2000; Dawe et al., 2000). Where a yield decline is reported, the major causes suggested are a gradual decline in the supply of soil nutrients because of inappropriate fertilizer applications, a decline in soil organic matter content, atmospheric pollution, pest and disease infestation, and negative changes in the biochemical and physical composition of soil organic matter (Nambiar, 1994; Yadav et al., 1998, 2000).

Soil productivity is closely linked with soil organic matter (SOM). Reduced productivity of rice–wheat system is attributed to declining (SOM), decreased soil fertility, occurrence of nutrient imbalances, and inappropriate fertilizer practices (Bhandari et al., 2002; Regmi et al., 2002). Accumulation of N is soil, hence sustainability, has been better in farms applied with organic fertilizer than synthetic fertilizer possibly due to slow release of N resulting in lower losses (Bhandari et al., 1992; Yadav et al., 2000). Organic fertilizers are also known to stimulate biological-N2 fixation in soil and may also be responsible for the increase in total soil N (Roper and Ladha, 1995).

Loss of agrobiodiversity. The ESAP is among the regions that harbor the richest reservoirs of biodiversity. Indeed, this region is center of origin of many of the crops and livestock that are of economic importance to man. Resource poor farmers are highly dependent on agricultural biodiversity e.g. minor crops, wild plants, soil biota, etc., for their livelihood activities. They may be insignificant in national statistics, but critically important at the local level. Biodiversity had been associated with farmers' production choices, food security, and coping mechanism to environmental uncertainties by spreading the risks to reduce potential impact. (Cromwell et al. __).

Genetic variability of species comes from genetic resources. Desirable genetic traits are identified by breeders from genepools and incorporate them to mainstream varieties to produce crops with desirable characteristics: improve yield, quality, pest resistance, tolerance to environmental constraints, etc. (Chang 1984). It is estimated that half of the increase in yield of major crops is due to genetic improvements from breeding activities.

The significance of biodiversity in agriculture perhaps is less understood and appreciated. These very important resources are being threatened due to simplification of ecosystems, and species and varietal replacement. Harnessing these wealth of biodiversity in the region have not been fully utilized due to predominant agricultural approach of monocropping and specialization which is most often reinforced by government policies in the form of input subsidies, agricultural extension messages, or widespread distribution of modern seeds by governments (Cromwell et al., __).

Monocropping, especially the green revolution crops, has displaced many local and traditional varieties, resulting to genetic erosion. From the 30,000 rice varieties traditionally cultivated in India, it now rely only on 10 varieties in producing 75 per cent of its rice. In Indonesia, 1,500 varieties of rice disappeared from 1975 to 1990 (WRI/UNEP/IUCN, 1992). Rice HYVs has displaced 80 to 82 percent of rice fields in Burma, Indonesia, Philippines, and Thailand. The thousands of farmer-developed rice varieties planted in mosaic pattern in agricultural landscapes are nothing more to be found, except, in the ex-situ gene banks of research institutions. Yet, biodiversity should be the best strategy to increases resiliency of agricultural systems. Perhaps, the only visible practice in agriculture incorporating biodiversity is agroforestry.

Loss of forest cover, coastal wetlands and other ‘wild’ uncultivated areas further exacerbated losses of wild relatives and losses of the wild foods that are essential for food provision (Cromwell et al.,). Habitat losses were serious in the Indian sub-continent, China, Philippines, Thailand, and Vietnam (ESCAP, 1995b).

Often, a fourth dimension of biodiversity, cultural diversity is least appreciated. But traditional / local knowledge is key to the use and conservation of biodiversity. It is this local knowledge which is an embodiment of the coping mechanisms of local people under varied and rigorous circumstances that make unique areas productive and sustainable. These local knowledge were ignored in the dominant agricultural systems and most of it are already disappearing.

“To fully benefit from the many advantages of agricultural biodiversity, effective and sustainable conservation process need to be in place. On-farm conservation should be an essential part, a complement rather than a substitute, for existing ex-situ conservation methods. Furthermore, in-situ or on-farm conservation should take into consideration the whole ecological system which is being cultivated since agricultural biodiversity includes not only genetic and species diversity but also diversity in ecosystems as a whole" (Cromwell et al.).

Pest/disease incidence and pesticides. The period under review was the advent of fertilizer and pesticide utilization. But despite the use of more pesticides, pests, diseases and weeds remained significant problems. Agronomic practices have their share in greater incidence of pests and diseases. Pesticides cause pest problems too because beneficial insects are also eliminated and pest resistance to pesticides evolves. For example, the brown planthopper outbreaks in rice during the 1980s was due to continuous irrigation, dense planting, high nitrogen fertilization and pesticides eliminating natural enemies of the pest. Currently, 500 insect pests, 150 plant pathogens and 133 weed species already had become resistant to insecticides (Brattsten et al. 1986; Altieri, 1992; May, 1993).

Intensive farming systems have many problems and are unsustainable. Intensive shrimp production is threatened by viral diseases. In livestock production, antibiotics had to be continuously administered. Some of the new diseases that emerged in a serious situation are bird flu and mad cow disease.

IPM was developed in the 1980s and it was quite successful in selected crops in the region. Indonesia officially adopted IPM as national policy in 1986, and after five years, it reported 70 percent reduction in pesticide use while rice yield increased by 10 percent.

Energy use and efficiency. Contemporary agriculture depends on ever-increasing use of fossil energy. The epitome of this over-reliance on fossil fuel was the green revolution, whose approach was designed at a time when fossil fuel production was at its extraordinary height, and whose price was extraordinarily low. Currently, the resulting industrial monoculture is extremely energy inefficient, and that price of fossil fuel is extremely expensive and it is fast running out.

Energy consumption in industrial agriculture is in production of nitrogen fertilizer, farm operations and irrigation.

Pretty and Ball (2) estimated that modern agriculture requires 6 to 10 times more energy than sustainable agriculture methods. Smaller farms are often more productive than bigger farms. In India, a 0-5 acre farm had a productivity of Rs. 735/acre while a 35 acre farm had a productivity of Rs. 346/acre.

Additional energy inefficiencies in current agriculture and food systems is the emerging increase in food miles of agricultural produce from production to consumption, shipped not only in the region, but across the globe.

Waste management. The industrial agriculture contributes largely to the emission of greenhouse gases. It is estimated that 20 percent of the global carbon dioxide emissions, 60 percent of methane gas emissions and 80 percent of nitrous oxide come from modern agricultural practices.

The GEO3 Report states that "Soil contamination has been increasing with cadmium (contained in fertilizer), hexavalent chromium, lead, arsenic, trichloroethylene, tetrachloroethylene and dioxin mostly in the northern parts of the region, and parts of Australia and New Zealand. (GEO Report). The contaminants affecting health arising from chronic poisoning from agricultural land were common in the 1970s in the northwest Pacific and northeast Asia (MoE Japan 2000). The major polluters in the region are now the chemical and electroplating industries in Japan and the Republic of Korea but heavy metals are also present in agricultural land (as a result of fertilizer application), and near mines and refineries (due to chemical discharges). Soil contamination from lead and arsenic contamination is prevalent throughout South and Southeast Asia. Irrigation with untreated effluent has also caused contamination and soil acidification in many areas; in Mongolia, for example, waste disposal and wastewater discharges are the main causes of soil contamination (UNDP 2000)."

Conflicting resource use. Due to the very fast population increase and industrialization in the ESAP region, agricultural lands are converted into residential and industrial uses. This further shrinks the arable lands used in agriculture. Land degradation problems are directly related to land-use practices, particularly agricultural expansion and intensification. Thailand's land use pattern has changed dramatically over the past 30 years, with forest land declined from 56 to 24 per cent of total land area between 1965 and 1997 (Donner 1978 and GWF 1999). In Japan, the area of agricultural land decreased from 5.8 to 4.9 million ha between 1970 and 1999 as arable land was converted to residential use (NLA 2000). In the Philippines, land conversion is at the rate of 45,000 hectares.

Response to natural calamities/disasters

Climate change. Productivity and sustainability of agriculture is increasingly threatened by global warming. Over the past hundred years, the warmest years occurred very recently: 1998, 2001, and 2003. Crop yields and animal production decline due to heat stress. Scientists from IRRI(1) have estimated that every 1 oC increase in average temperature causes a drop of 10% in rice grain yield. The IPCC projected a decline in grain harvest in the tropical regions of 5-11 percent by 2020 and 11-46 percent by 2050 mainly due to high temperatures. More severe damage if extreme temperatures occur during embryonic stage or flowering/fertilization in crops.

Climate change will have profound effect to an estimated 500 million rural poor living as subsistence farmers and occupying mainly rainfed land within ESAP (ESCAP, 1995a). The drought-prone countries in this region are Myanmar, Pakistan, Nepal, India, Sri Lanka, and parts of Bangladesh. About 33 per cent of the arable land (14 per cent of the total land area) in India is considered to be drought-prone, and a further 35 per cent can also be affected by drought when rainfall is exceptionally low for extended periods (ESCAP, 1995a). Also, the Philippines, Thailand, Nepal, Australia, and the Pacific islands of Fiji, Vanuatu, and Samoa contain drought-prone areas (GEO1 Report).

Climate change is said to have influence on tropical cyclones, or typhoons, which is becoming stronger and more frequent. These are very common in Asia and the Pacific, occurring most frequently over the north-west Pacific with an average of 30 typhoons per year (38 per cent of the world's total) (ESCAP, 1995a). In the Bay of Bengal, tropical cyclones usually affect India and Bangladesh, causing severe flooding and devastating tidal surges. The cyclones generated in the South Pacific frequently cause devastation in Pacific countries such as Fiji, Tonga, Vanuatu, Solomon Islands, and Samoa. The Philippines, Bangladesh, and Vietnam suffer most frequently from these large events (GEO1Report).

The current mainstream approach of agricultural monoculture is bound to be relatively more adversely affected compared to diversified approaches. Overall, the better way to cope with stochastic events such as droughts, typhoon, etc. is to build resilience of agricultural systems. (Scheffer et al., 2001).

Summary

The current industrial agriculture was predicated on unlimited growth and technocentric approaches. But these cause collateral environmental damage and are unsustainable. It is therefore imperative to develop new approaches and examine new models of agriculture for higher productivity, energy efficiency, and sustainability. Agricultural knowledge, science and technology have to move toward conservation and full utilization of biodiversity and minimizing ecological footprints. Degraded land should be regenerated, and the soil has to be brought back from carbon source to carbon sink. Local knowledge and socio-ecological context has to be incorporated in the design of agricultural technology to be generated if sustainability and efficiency are to be attained. Moreover, involvement of all stakeholders: scientists, local farmers, governments, and private sector.

2.4.15 Social equity and sustainability

This subchapter looks at the impacts of AKST (Agricultural Knowledge, Science and Technology) on equity with a special focus on disadvantaged groups such as poor farmers, women, indigenous and tribal people from Asia and the Pacific. Sustainability refers to managing resources to maintain themselves on a daily basis and ensure that they have what they need as they move from one annual cycle to the next and from one generation to another (M.S. Swaminathan Research Foundation, 2002). Without equitable distribution, this aspiration of sustainability would not come. Gender, class, caste, ethnicity et al continue to institute an asymmetrical access to wage, land access, tenure, management, and decisions making structures within households and community organizations. On the issue of AKST, it is essential to learn how AKST contributes (or not) to social equitability. For instance, is it applicable to diverse groups or has it been successful in certain communities, is AKST reducing the gap between rich and poor, women and men? Is benefit of AKST reaching equally to all or is it reaching to only part of society? The assessment is done at the community level as well as intra-household level.

Employment Opportunities and Income Distribution: New AKST has created new job opportunities for poor farmers, women and indigenous people and helped to reduce poverty in some cases however the benefit of these new opportunities are varied between gender, class and caste. The studies conducted (Otsuka and Yamano, 2006) in the Philippines, Thailand, Bangladesh, and India on the role of non-farm income in long-term and short term poverty reduction show drastic increase in non-farm income and is declining in poverty levels over time, especially in the Philippines and Thailand. Education levels of household members and returns to education also increased significantly in these countries. Further, another study conducted in Bangladesh on employment effects on modern agricultural technology in crop production, it was found that the increased demand for labor owing to technological change is mostly met by hiring male laborer. The few women haired are paid significantly lower wages than men. Further, it is reveal that there were unequal opportunities for women and a lack of bargaining power for women in the hired labor market (Rahaman and Routray, 2001). Besides that, the impact of new technology on women varies between different categories of women. One study in Vietnam found that promotion of plastic row/drum seeder technology in rice planting has displaced poor women from farming households who worked as wage laborers in hand–weeding and gap–filling. The poor and landless women face the worst consequences due to a lack of alternative job opportunities and increases in debts. Whereas progressive farmers who had more frequent contact with extension workers, had better–educated wives, and used low seed rates were more likely to benefit from this new technology (Thelma and Truong, 2005). The case study in India and China shows family farming focusing on small producers was attractive on both equity and efficiency grounds (Lacy, Lacy and Hansen, 2003).

If we look at income distribution at household level, generally, it is hard to say how much women and men's incomes have increased after using AKST as most farmers are involved in different activities which have different incomes. Studies in Bangladesh have shown that some women are involved in vegetable growing where their income is negligible and most of their income and vegetables are used for home consumption. Whereas another study showed that women's involvement in fish production in Bangladesh did not help them specifically as men did the trading so women never knew how much was being earned (Naved, R. T., 2000). Use of new groundnut technology in India and intensified aquaculture in Thailand and Vietnam has shown that while the additional income gained is small in amount, women did gain control over additional income and this amount is generally used for daily consumption. If the increased production is more than consumption at home, the extra amount can be used for trading and eventually men benefit from it (Kolli and Bantilian, 1997: Kusakabe 2002).

Hence, these observations indicate that though intervention of technology is likely to convert traditional farming system into more entrepreneurial systems and add to family income; however, it is necessary to examine in detail the equity implications of the benefits derived by each member of the farm household. Usually planners think that the household is a unit and benefits from certain activities are distributed equally to all household members; however the case studies narrated above have shown that in order to increase weaker group's/women's choices, it is important that household income should have from various sources to negotiate their priorities. Diversification of sources of income is not only desirable for reading risks and increasing the household income but also control over economic activities among members of the household (Kusakabe, 2001).

Assets and Land ownership: Land is the most basic resource of agricultural production. The prevailing system of land ownership has an implication on a person's position, power and status within the household and community.

For instance, land ownership is one of the most important criteria that influence the negotiating and decision-making capacity of women within the household (Crowley, 2001). However, women's ownership of land may not always give them the control over land as study showed in Kerala, India (Arun, 1999). The recognition of women's differential access to property and their lack of command over its use even if they own it should be the starting point of a gender-sensitive agricultural policy. The gender gap in the ownership and control of property is the single most important contributor to the gender gap in women' s economic wellbeing, social status, and empowerment (Agarwal 1994). It is important that women have direct access to critical farm inputs, to enable them to maximize outputs, challenge ideas of `women's work', and thence to gain control over the other factors of production and change social norms. Most importantly, there should be a concerted effort to enable women to function as independent farmers who control their own land (Arun, 1999). Enhancing land rights of weaker group of the society, requires that they become a political priority and a legal possibility; it also requires administrative viability, social acceptability, and moral legitimacy (Crowley, 2001). There is need of complementary policies, which address women's limitations in exercising and enjoying their land rights.

Poor people and women generally have fewer assets than the non-poor. This means that agricultural technologies that require a high level of assets to adopt are more likely to exclude the poor from direct benefits. Even with assured land rights, investments in property require access to financial markets and information, extension, and other services. The study conducted in Bangladesh (Meinzen-Dick,R. and et. al 2003), showed that the choice of new technology and it's impact is different. The improved vegetables were disseminated to poor women, who could grow them on their homestead land so poor families without land (only have homestead land) could also participate. In contrast, one of the fishpond programs focused on those with private fishponds, who tended to be non-poor. Moreover, homestead land is more under women's control. Farmland (including fishponds) is more likely to be under men's control. Hence, the vegetable program reached women as well as the very poor, whereas control of output of the private fishpond program went mostly to men. Given the gendered nature of poverty, it is important that these differences in control over assets and technology are considered while planning and implementing a project.

What is more important is women's control over key economic resources rather than mere economic ownership or their participation, this is critical to their power within the family. When women not only earn but also control the use of their income, they can use it more effectively as a bargaining chip with the implicit threat of withdrawing it from the household economy. It is recognized that women's ability to exercise control over their own earnings depends largely on cultural traditions, age, stage in family life cycle, and social class (Naved, 2000). Policymakers should be aware of the complexity of gendered nature of ownership and tenure systems. Then they can put legal principles associated with land rights into practice.

Work Load and Time Allocation for Resource Production: Time is an important resource for any body for internal development. The lack of time limits people ability to participate in and benefit from development activity particularly at the decision making level. The allocation of time to various activities, particularly by women is significantly influenced by the introduction of the technology (Kolli and Bantilan, 1997). The time allocation of women and men for productive, household, social and religious activities differs significantly by season and production environment. As below charts (Fig. 2.4.5.1, Fig. 2.4.5.2 and Fig. 2.4.5.3) show, that women work longer period than men in all activities and production environment (Sharma, 1995) in all seasons in Nepal (Shrestha, 2001) and in all age group in Vietnam (Balkrishnan, 2005). Due to male's migration in cities, women's and children's agricultural work load increased (Balkrishnan, 2005). However, in another hand, due to introduction of new agricultural technology, women's agricultural workload has been dropped to about 30 percent of the previous workload in Southern Vietnam (Ba and Hien, 1996). This saved time is utilized through other subsistence activities such as aquaculture in homestead land, home gardening, craft activity etc. and sometime they shift from one activity to another activity (Felsing and Baticados, 2001). Although, additional income might be gained by this additional activities, there is a necessity to examine the benefit of labour and time saving due to use of AKST, which is equitably distributed to all the members of household or not. However, another study in Indonesia and Malaysia has shown that these additional activities including aquaculture add to women's workload while profit goes to the men. Because traditional structure of patriarchy are stronger and their challenging women's traditional role within the household remains the biggest task ahead (Burgere, 2001). Similar conclusion of benefit of increased time allocation and workload did not benefit women from decision-making power with respect to use of resource and crop utilization in groundnut technology in India (Kolli and Bantilan, 1997). It is worth the increase of working time and workload, if the benefit gained from overwork goes directly to the people who are in subordinate positions and the actual user of the technology.

[Insert Table 2.23: Time Spent by Men and Women for Overall Activities in Rainfed and Irrigated Working Environments]

[Insert Figure 2.22: Time Spent by Women and Men in Domestic Work on Working (left) and Non-Working (right) Days in Different Communities in Nepal]

[Insert Figure 2.23: Men's and Women's Average Hours Spent in Household Maintenance Activities in Vietnam, 199798]

Access and control over resources: Control over resources is an important factor for the growth in the society. Empirical studies have shown that farmers with more education, land and farm tools are likely to adopt new technologies compared to those who have less. The poorer farmers are becoming more landless and moving to cities in the search of other jobs. Similarly, women who have less education, access to farm land and tools will obviously have less access to newer technologies (Quisumbing, 1995). Further, if we look at household level, as the activity becomes more intensified or larger in scale, women lose control and men take over. For once it is commercialized, market information becomes more important for growth of this activity. Women's lower mobility, lack of access further reduces control over the production process. This has been revealed from a case study conducted among women involved in subsistence aquaculture, semi-intensive and intensive aquaculture activity in Thailand and Vietnam (Kusakabe, 2001).

The case study from Bangladesh, shows, small scale aquaculture, specially in small ponds, ditches or rice-field plots identified as the best alternative for poor farmers to ensure fish supply for household consumption and income generation. However, the involvement of women is limited due to women's on mobility. The study had shown that there is great potential for women to integrate of crop-livestock-fish-within home stead areas. (Barman, 2003). Another study carried out again in Bangladesh (Naved, 2000) on the intra-household impact of transfer of modern agricultural technology found that group-based programs targeting women have a greater potential to address gender equality within the household and society than programs targeting women as individuals. In male-dominated societies where women have limited access to internal or external support networks, programs targeting women as individuals, which do not also provide alternative sources of support are bound to fail in their gender goals, whereas in group based program, husband can not take over the resources gained from the program.

Gender roles and AKST: Our literature review shows that there are key concerns related to social equitability; For instance women are the major stakeholders of the agricultural production. Though they are the managers and 'executors' (workers) in this mode of production; their involvement in this sector has been completely ignored. Their economic contribution is either not counted or under counted in national economy (Agrawal, 1985). For instance, a research conducted in Nepal (Joshi, 2000), like many national statistical surveys, the Agricultural Census of Nepal does not reflect the actual contribution of women's work in agriculture due to inadequacies in conceptualization definition of terms and data gathering methods. After analyzing the gender division of labor, it was found women contribute much more higher than men do. Further, this fact has been supported through the time use surveys conducted in different selected countries in both developed and developing countries in Asia Pacific, women are the major stakeholders of the agricultural production and their time contribution to agricultural production is higher than men in the region (See table 2.4.5.1.)

[Insert Table 2.24: Gender, work burden and time allocation in selected Asia and Pacific countries]

As above table, show that although women contribute a lot or spend more time in agriculture related activities, the predominant image of a farmer in both developing (Agrawal, 1985) and developed countries (Alston, 2004) of ESAP is male and therefore, policies and programs ignore women's needs and concern as a farmer (ADB and UNIFEM, 1990). The accuracy of national level statistics serves as the principal data input in the framing of development policies. It, is a leading factor to an under counting of women both as workers and as those available for work (Agrawal, 1985). Their contributions are either unrecognized and undervalued (Alston, 1998; Siason and et al, 2001). There is a need of intervention to recognize unpaid work. However, agricultural planners continue to overlook women's participation as well as their training and educational needs (Paris et al, 1992; Punia 1991) and there is no clear policy direction promoting women in this subchapter (Siason and et al, 2001). There is still need to improve the gender planning capacities of national agencies (Balakrishnan, 2005).

Awareness about gender issues and incorporating their needs and priorities in the planning process is increasing and some steps are being taken to integrate women's concerns (Quisumbing, 2003, Kelkar 2005). There are still many ignored concerns, which need to be understood. In that aspect not enough research is being done, especially on the impacts of AKST. Other issues that came up in our literature review are: gender disaggregated data, which is necessary for the appropriate intervention and policy changes are lacking or under reporting in developing countries (Siason and et al, 2001) as well as developed countries such as Australia (Alston, 1998). Attention to women's work, drudgery of daily labor and inequitable access to resources are still required as well. These are imbedded in gender biases, which are carry on through cultural conditioning and social norms, at both the household and community level (Balakrishnan, 2005). Women's contribution in time to household and agricultural production has been much higher than men's (in working hours). However, there is no attention to the production of labour and time efficient devices, which can minimize the drudgery of women's work (Shrestha, 2001).

Sex-based division of labour prevails in all social systems. In such systems, traditionally, women are allotted most of the jobs in the domestic sphere and time consuming drudgery tasks in the fields. However, although basic roles are remain, some of the divisions between women and men are changing. People's perceptions are slower to change than what women and men are actually doing, such as both women and men consider fishing as men's job; while actually, women are almost equally involved in fishing activity in Yunan, China (Yu Xiaogang, 2001). Gender division of labor is not static and changing over time and situation (Kusakabe, K. 2002). The study in China showed that women's involvement in fishing changes with environmental and economic changes (Yu Xiaogang, 2001). Hence, gender based division of labor in the outside production is changing over time either due to introduction of technology or environmental changes or economic changes, however it is hard to see drastic changes in division of labor at household level. Women are taking more and more of their responsibilities on production side whereas their household work still remains on them. This over burdens women with workload and creates a lack of time for their self-development, which is again an enforcement of gender inequality.

Different studies carried out in Asia and the Pacific show that measures of the direct impacts of new technologies on incomes and yields do not tell the whole story. Both economic and non-economic factors (such as sources of vulnerability, gender roles, and the source of the disseminated technology) play an extremely important role in determining whether the poor and weaker group of society benefit from a technology. In addition, social, cultural, and economic factors all influence whether the poor receive direct and indirect benefits from new technologies. In this subchapter we looked though some parameters as in income distribution within families and communities. Similarly, has land ownership played a role in acquiring benefits from AKST; who has access and control over resources; how has technology played a role in workload and time allocation; and who benefits from this. Is there any change in gender roles and gender based division of labor? Has there been any change in the decision making process on production and consumption at household level and community level?

Decision making pattern: Decision-making over the use and management of technology differs according to type of technology used and nature of activity people perform. The study conducted in different countries, over all women are lagging behind compared to men, such as decisions on adaptation of modern technology in Bangladesh (Rahaman and Routray, 2001), decisions on use of technology in India (Singh, G., G.Singh and N. Kotwaliwale. 2000). Similarly, the improved technology developed by research and development institutions have mainly focused o male worker (Singh, G., G.Singh and N. Kotwaliwale. 2000).

The study of rice-fish farming system in Indonesia resulted in increased income, however despite women's involvement in transplanting, weeding and rice harvesting, women's decision making role in production was low and they were not involved in farmers meeting and classes. In order to build women's decision-making capacity, it is important that women have equal access to information as men (Wardana, and Syamsiah, 1990). If the improved technology creates greater demand for market-related activities, men maintain or increase their control over these activities. The traditional assignments of market-oriented activities means that the technology introduced contributes to reinforcing stereotyped gender roles and, in the process, reduces the control of women over resource use (Kolli and Bantilan, 1997) (as shown in case study from India). Therefore, it is necessary to build the capacity of women on market related activities in tandem.

The training provided to poor women on small-scale aquaculture enterprise management in Vietnamese integrated farming system (garden/pond/animal husbandry) in two Northern provinces of Vietnam shows that after training, women gained knowledge, which helped them to take more decisions in the management of aquaculture. In addition to this, it is also from their contribution of food security and income generation activity as well. Once they have taken more decisions in aquaculture management, their position in the household strengthened (Voeten, J. and B.J. Ottens, 1997).

Conclusions: The case studies above illustrate that a) all farmers are not a homogenous group so needs and priorities of technology are different for different groups; b), because of gender division of labor in agricultural activities, women and men have different experiences. Due to their different experiences, women have different 'knowledge resources' from men, whether it is on market, tools, or techniques. It should also be noted that since all farmers are not a homogeneous category children, women, men, indigenous people, farmers of different ages, ethnicity, and class will be engaged in different activities, and their experience and thus local knowledge would also be different. Thirdly, household is not a monolith, and there is both a complimentary role and conflict in interest and needs between husbands and wives and between different members in the household. Therefore incomes will not be distributed equally amongst family members unless the project is well planned and conceived. In the end, information and capacity building for women, children and indigenous people is an important component to bring about equality, which has to go together with new technologies in agriculture system.

Many countries in the Asia and the Pacific region recognize that in addition to training and group meetings, there is a potential of Information and Communication Technologies to improve women and children's access to information and knowledge, enhance their education and learning, and accelerate technology transfer. Radio and television are used extensively in several countries to inform and educate rural women about topics such as health, nutrition and agriculture (Balakrishnan, 2005). The most well known case studies of ICTs potential benefits for rural women's livelihoods are: Bangladesh Grameen Communications' venture of rural women's cell phone enterprises; M.S. Swminathan Research Foundation supported Pondicherry Village Information Shops; e-Chaupal for market information; SEWA's programme on skills development to support women's work in the informal sector; Sri Lankan Kotmale project and information kiosks and telecentres in the region (Balakrishnan, 2005). Despite the potential (Kelkar, Shrestha and Veena 2005), there is a threat of an increased "digital divide" that would widen information, education and knowledge inequality between women and men, rich and poor or urban and rural communities. Therefore, it is necessary to ensure that new agricultural technologies are appropriate for the different groups of people who most need assistance. Furthermore, it is necessary to assess whether these new technologies actually reduce poverty and inequality.

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